INTERIM FEASIBILITY REPORT

LONG ISLAND SOUND

THAMESVILLE TIDAL

FLOOD MANAGEMENT

WATER RESOURCES STUDY

NORWICH, CONNECTICUT

AUGUST 1987

US Army Corps
of Engineers
New England Division

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THAMESVILLE
TIDAL - FLOOD MANAGEMENT
WATER RESOURCE STUDY
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New England Division, Corps of Engineers
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REPORT OF FEASIBILITY

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EXECUTIVE SUMMARY

This study identifies and evaluates the feasibility of alternative tidal flood management measures in the Thamesville section of Norwich, which is located near the head of the Thames River estuary in southeastern Connecticut. Thamesville has experienced severe flooding in the past, with the 1938 hurricane producing the record flood resulting in up to nine feet of water in the area. Under today's conditions, if this flood were to reoccur, it is estimated that damages would total $9 million.

Whereas in 1938 there was fresh water flooding in Thamesville, a repeat of fresh water flooding will not impact this area significantly since the Corps has since constructed in the upper basin six flood control reservoirs. These projects provide over 148,000 acre-feet of flood water storage upstream of the Thamesville damage zone. These improvements have greatly reduced the potential for fresh water flooding that would further surcharge tidal flooding. There remains a significant tidal flood problem which has been the focus of this study and report.

Initial studies considered high levels of flood protection for a tidal frequency storm in excess of 500 years. These higher levels of protection were found to be only marginally justified. Local interests who participated in our plan formulation preferred lower levels of protection. Accordingly two alternatives considered structural protection for 100 year and 20 year tidal flood events. These plans are described in detail in this report. A third non-structural plan, Alternative #1, provides for flood warning and evacuation procedures, and effects the least cost while providing significant benefits.

The structural floodwalls referred to as Alternatives 2A and 2B provide protection for the high damage cluster of businesses, specifically, Lehigh Oil, American Thermos, Sawyer Displays and United Metal, as well as some nearby residential properties. Alternative 2A provides protection from a flood event with a 5% chance of being equaled or exceeded in any given year, whereas Alternative 2B provides protection from a flood event with a 1% chance of being equaled or exceeded in any given year. Although both alternatives were found to be economically feasible, they were not preferred by local interests.

Alternatives 3A and 3B provide for structural floodwalls around the entire Thamesville industrial, commercial and residential area. Alternative 3A provides the same level of protection as Alternative 2A, and Alternative 3B provides the same level of protection as Alternative 2B. However, neither alternative is economically feasible.

In summary, plan formulation evaluations have shown that alternative approaches to reduce flood damage potential are available and were found to be economically feasible. Options include expanding the existing nonstructural flood warning and evacuation system, or building floodwalls to keep floodwaters out of a high damage cluster of buildings. While flood warning and evacuation would not prevent flooding, the benefits outweigh the relatively small implementation cost.

Our studies have revealed lack of support by the State, the city of Norwich and the individual property owners for structural floodwalls as found justified and known as Alternatives 2A and 2B. Reasons for this are that over the years local interests have accpeted the risks of flooding and have relocated inventories within the plants to higher elevations, consequently sustaining minimal flood losses in the event of tidal flooding.

Duirng our studies we asked the building users if they were utilizing the flood insurance programs to ameliorate the stress from flood. It was determined that approximately one-third of the property owners in industrial zones carry flood insurance, one-third do not, and there are some that are unaware of whether their parent company carries flood insurance.

In summary, this report recommends the implementation of Alternative #1, a completely nonstructural plan, which is in keeping with State and local desires and which can be implemented well within the financial resources of the State, city and private interests.

SECTION I
INTRODUCTION

STUDY AUTHORITY

This study is authorized by a Resolution of the Senate Public Works Committee, adopted 22 September 1970, which states:

> "That the Board of Engineers for Rivers and Harbors, created under Section 3 of the River and Harbor Act approved June 13, 1902, be and is hereby requested to review the report on the Land and Water Resources of the New England-New York Region, transmitted to the President of the United States by the Secretary of the Army on April 27, 1956, and subsequently published as Senate Document Numbered 14, Eighty-fifth Congress, with a view to determining the advisability of improvements in Long Island Sound, New York and Connecticut in the interest of flood control, navigation and related purposes with due consideration for enhancing the quality of the environment."

BACKGROUND

The Corps of Engineers has previously addressed the flood hazards on the Thames River. These included the 1927 River and Harbor Act (House Document 308, 69th Congress 1st Session) which directed that studies be made and the subsequent "308" Reports in 1930 which found that improvements were not warranted, a 1940 report which recommended channel improvements in Norwich and the construction of several flood control reservoirs in the Thames River basin, and several reports done since 1950 regarding flood control reservoirs in the upper basin. As a result, the channel improvements and six reservoirs were completed, along with the New London Hurricane Protection project. (see Figure 1).

After the 1954 and 1955 hurricanes, the Corps of Engineers conducted a hurricane protection study in Thamesville between 1959 and 1962. This study identified an economically feasible dike/floodwall project at Thamesville, but the lack of local support and commitment resulted in no recommendation for this project.

The 1975 Long Island Sound Comprehensive Report, a regional plan of the New England River Basins Commission (NERBC), addressed the flood hazard at Thamesville and recommended that the Corps of Engineers perform additional studies at Thamesville, as well as six other tidal flood prone areas, with emphasis on nonstructural measures. The six other areas were Montville (also on the Thames River), the Ocean Park area in New London, Old Lyme, Stratford, Fairfield and Westport. The NERBC study also indicated that flood losses in highly developed flood plain areas could be cut by structural solutions, even though these measures have been rejected by local interests in the past, as was the case at Thamesville, because of high costs and environmental impacts. In 1981 the Corps of Engineers completed a Reconnaissance Report for Thamesville. That report identified the problems, needs and opportunities for developing alternative solutions to reduce tidal-flood damage. This document reports on their feasibility.

SECTION II
PROBLEM IDENTIFICATION

STUDY AREA

The Thamesville project area is a 35-acre industrial and commercial development constructed on fill along the west bank of the Thames River about one mile south of Norwich and 16 miles north of New London, Connecticut. The river, which drains a watershed of 1382 square miles at this point, is a tidal estuary. There is a federal navigation channel in the river which is maintained to a 25-foot depth in the Norwich area.

LAND USE

Land use zones in the Thamesville project area have been classified as heavy industrial bordered by general commercial and multi-family residential. The flood area is bisected in a north-south direction by the main line of the Central Vermont Railway. There are approximately 40 buildings and storage tanks in the project area. The residential land use classification includes both single and multi-family dwellings. The commercial and industrial classifications include the following (see Figure 2):

- Norwich Iron (salvage operation)
- United Metal (metal coating)
- Nutmeg Wire (wire fabrication)
- Abbot Seafood (storage of canned and packaged foods)
- American Thermos (storage)
- Sawyer Displays (manufacture of counters and displays)
- Dahl Oil (fuel oil storage and distribution)
- Lehigh Gas (bottled gas distribution and retail sales)
- Lehigh Petroleum (fuel oil storage and distribution)
- Connecticut Beverage Company (distribution)
- Refridgerated Warehouse (vacant - formally Sachem Produce)
- DOCO (part of Dahl Oil - tires and lubricants)
- Sign Design (manufacture of signs)
- Cham Equipment (car and truck repair)
- General Dynamics (storage)

WATER QUALITY

The Thames River Basin has been experiencing long-term degradation from approximately 65 significant municipal, domestic, institutional and industrial point source discharges, as well as nonpoint source discharges such as urban runoff. Within the 15 mile stretch of the Thames River from Long Island Sound to Norwich, 14 significant point source discharges have been identified. One of the major water quality problems in the Thamesville area is the combined sewer overflows in the city of Norwich. The city is presently implementing a phased program to correct this problem.

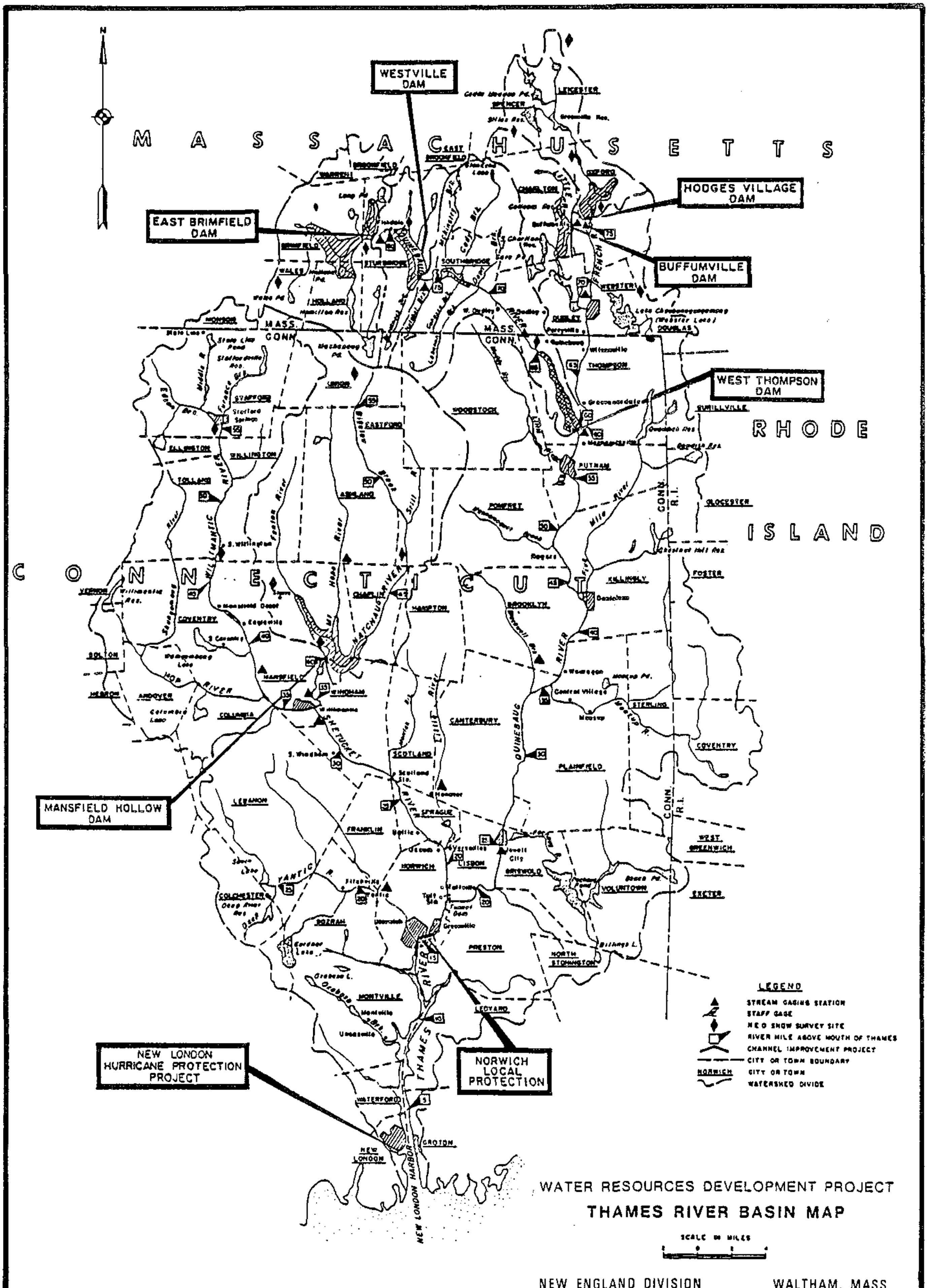

WESTVILLE DAM
HODGES VILLAGE DAM
EAST BRIMFIELD DAM
BUFFUMVILLE DAM
WEST THOMPSON DAM
MANSFIELD HOLLOW DAM
NEW LONDON HURRICANE PROTECTION PROJECT
NORWICH LOCAL PROTECTION
MASSACHUSETTS
RHODE ISLAND
CONNECTICUT
LEGEND
STREAM GAGING STATION
STAFF GAGE
CITY OR TOWN BOUNDARY
CITY OR TOWN
WATERSHED DIVIDE
WATER RESOURCES DEVELOPMENT PROJECT
THAMES RIVER BASIN MAP
NEW ENGLAND DIVISION
WALTHAM, MASS.

FIGURE 1

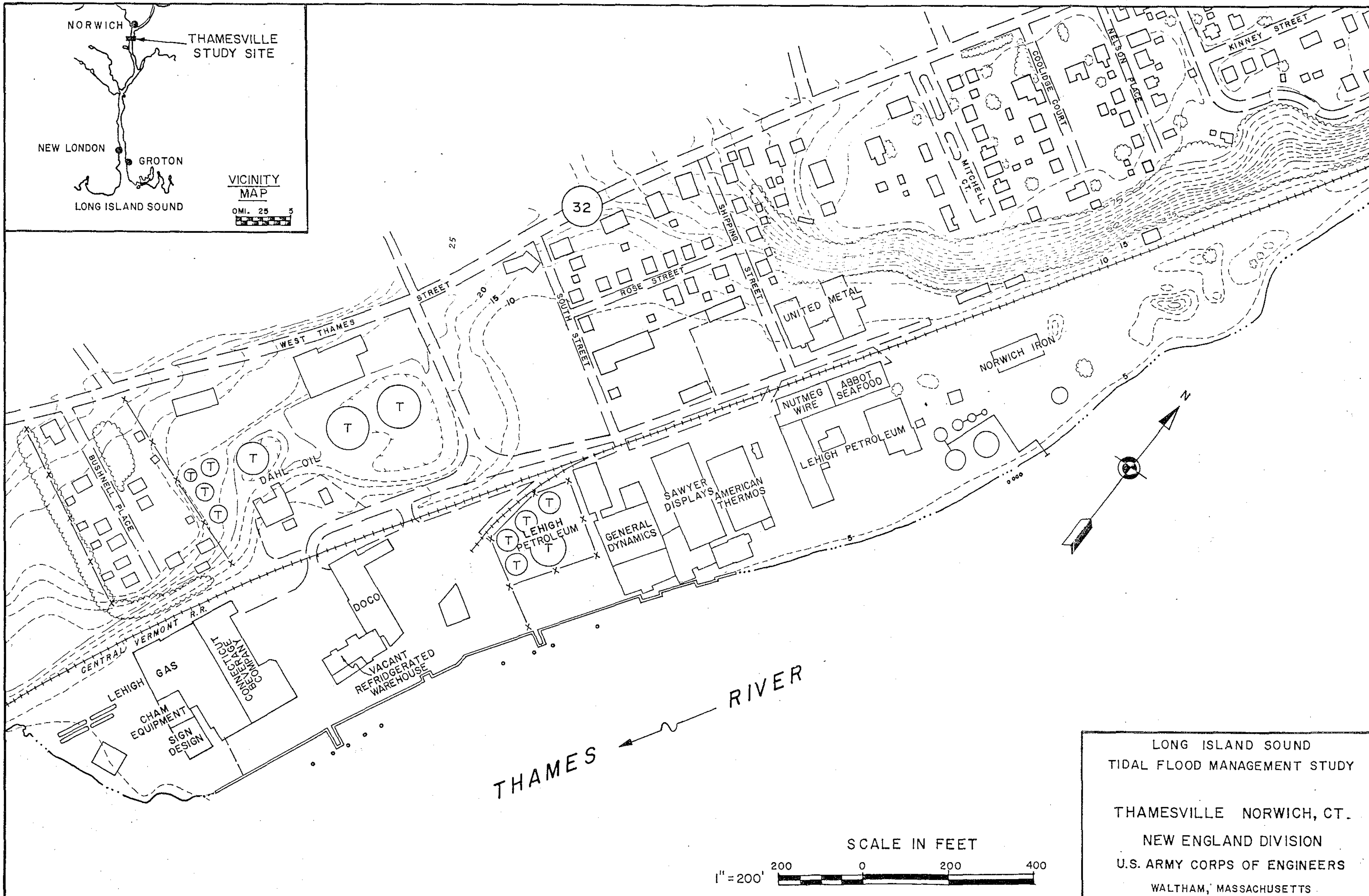

NORWICH
THAMESVILLE STUDY SITE
NEW LONDON
GROTON
LONG ISLAND SOUND
VICINITY MAP
0 MI. .25 .5
32
KINNEY STREET
NELSON PLACE
COOLIDGE COURT
MITCHELL CT.
SHIPPING STREET
ROSE STREET
SOUTH STREET
WEST THAMES STREET
BUSHNELL PLACE
UNITED METAL
NORWICH IRON
NUTMEG WIRE
ABBOT SEAFOOD
LEHIGH PETROLEUM
DAHL OIL
SAWYER DISPLAYS
AMERICAN THERMOS
GENERAL DYNAMICS
LEHIGH PETROLEUM
DOCO
VACANT REFRIDGERATED WAREHOUSE
CONNECTICUT BEVERAGE COMPANY
LEHIGH GAS
CHAM EQUIPMENT
SIGN DESIGN
CENTRAL VERMONT R.R.
THAMES RIVER
N
SCALE IN FEET
1" = 200'
200 0 200 400
LONG ISLAND SOUND
TIDAL FLOOD MANAGEMENT STUDY
THAMESVILLE NORWICH, CT.
NEW ENGLAND DIVISION
U.S. ARMY CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

FIGURE 2

Under the State of Connecticut Water Quality Standards the Thames River has been classified as SC from Norwich to Long Island Sound, due to combined sewer overflows, with a future goal of SB. This SC classification indicates that the Thames is suitable for fish, shellfish and wildlife habitat, recreational boating and industrial cooling, and has good aesthetic value.

AQUATIC ECOSYSTEM

The Thames River estuary in the project area is subject to tidal fluctuation. The salt wedge extends up the Shetucket River to the Route 2 bridge in Norwich during summer low flows. When high freshwater inflow occurs with an ebbing tide, the head of the salt wedge may be pushed several kilometers downstream. Estuarine systems are usually very productive. However, use of the Thames and its shoreline for industrial development, commercial navigation, and waste assimilation has lowered its productivity as compared to other estuaries.

The river in the project area supports a diverse fish population including warm and cold freshwater species and some saltwater species. Principal fish species known to occur in this stretch of the river from Norwich to Stoddard Hill State Park, about five miles downstream from Norwich, are: bluefish, snapper bluefish, Atlantic mackerel, Atlantic tomcod, striped bass, white catfish, American eel, rainbow smelt, alewife, and white perch. The diverse fishery exists because many species migrate into the estuary for feeding, spawning and use of nursery habitat.

The Connecticut Department of Environmental Protection has placed high priority on the restoration of anadromous fish in the Thames River system. Historical records indicate that the river once supported runs of American shad, Atlantic salmon and alewives. The Thames River has been listed in an Alternative Action Plan for salmon restoration. There is, however, no stocking of Atlantic salmon at present.

Sea-run brown trout smolts have been stocked upstream from the project area since 1971 as part of an evaluation for Atlantic salmon stocking. Adults have been recorded approximately one mile upstream from the project area at the base of the Greenville dam, the lowermost dam on the Shetucket River in the city of Norwich.

The lower portion of the Thames River estuary supports some shellfish populations. The blue crab, *Callinectes sapidus*, is making a comeback and provides a small recreational fishery. The lower portion of the estuary also produces the American oyster, *Crassostrea virginica*, hard-shell clams, *Mercenaria mercenaria*, and soft-shell clams, *Mya arenaria*, but they are not taken for direct consumption due to high coliform counts. Readily available data do not indicate the nature of shellfish populations or those of other benthos in the project area, located in the upper portion of the estuary.

TERRESTRIAL ECOSYSTEM

The Thames River area has been heavily urbanized. Residential, commercial and industrial developments have been located along the banks of the river. The Thamesville project area is completely developed except for some vacant land south of South Street and a small parcel between South and Shipping Streets. There are no forested areas. The only wetland resource is the Thames River itself. Vegetation is limited to landscaped areas, ornamental plantings, gardens and isolated pockets of plant growth along fences, buildings and storage areas.

There are no wildlife management areas, refuges or preserves within the study area. Since Thamesville is highly developed there is little diversity of terrestrial wildlife. Mammalian wildlife which typically occurs within an urban environment such as Thamesville includes rabbits, squirrels and rodents.

HISTORY OF FLOODING

The Thames River estuary at Thamesville is subject to tidal and riverine flooding. The entire length of the Thames estuary is affected by tidal fluctuations from Long Island Sound to the confluence of the Yantic and Shetucket Rivers. Tidal flooding has occurred most frequently as a result of extratropical storms with southerly gales, but the highest levels of flooding have occurred coincident with hurricanes passing to the west of the area.

Periods of intense rainfall produce high riverine flows. However, the threat of riverine flood flows at Thamesville has been reduced since the construction of six Corps of Engineers flood control reservoirs in the upper Thames River Basin.

In the case of the 1938 hurricane, river flows were already high from 4 to 5 days of heavy rains. Therefore, when the hurricane arrived the flooding situation worsened due to the combination of high stages from river flow and a hurricane tidal surge.

The 1938 hurricane produced the flood of record along the Shetucket and Natchaug Rivers. Intense rainfall of 10-14 inches prior to the hurricane arrival resulted in serious river flooding from 17 to 21 September. Consequently, with the coincidence of high tidal and extreme river flooding, the record water level at Norwich occurred on 21 September 1938 when the river rose to 14.5 feet NGVD. The maximum observed at Thamesville was 14.2 feet NGVD.

Generally, it is tidal surge alone or in combination with high riverine flow that is the principal cause of flooding at Thamesville. High river flows at normal tides are not a major problem.

FLOOD DAMAGES

There have been two flooding events in recent history that have caused significant flood damages. The flood of record in 1938 inundated Thamesville with up to nine feet of water which is indicated by a high water mark inside the doorway of United Metal of Connecticut. Should this flood reoccur under today's conditions damages would total an estimated $9 million. The next highest flood, which occurred in 1954, was four feet lower and would have estimated damages under today's conditions of $5.4 million. Flood damages begin at about elevation 6 ft. NGVD which has about a 50 percent chance of being equaled or exceeded in any given year. During Hurricane "Gloria" in September 1985 high water marks up to elevation 7 ft. NGVD were noted. Flood damages, primarily to bulkheads, docks and grounds were generally insignificant, although the condition of the deteriorating river banks and bulkheads worsened. Water was about one foot deep on the ground level floor of Sawyer Displays. Potential average annual damages at Thamesville are estimated at about $815,000, a statistical estimate discussed in Appendix 4 - Economic Analysis, so the losses converted to an annual basis can be compared with potential benefits converted to an annual basis. A detailed analysis of the flooding problem is contained in Appendix 1 - Tidal Hydrology.

EXISTING FLOOD DAMAGE REDUCTION MEASURES

Upstream Flood Control Reservoirs. As mentioned previously, flooding originates from riverine or tidal sources, or a combination of both. The riverine flooding potential has been drastically reduced by the construction of the six Corps of Engineers flood control reservoirs. In a combined tidal/riverine flooding event such as 1938, the reservoirs are estimated to reduce stages by about one foot. The stage reduction is much more significant for the 1954 flood where the reservoirs would have reduced stages by more than three feet.

Flood Warning. During flood periods the Corps of Engineers operates its six reservoirs to provide protection for all downstream communities. The Northeast River Forecast Center at Bloomfield, Connecticut is responsible for preparing and disseminating flood forecasts. The State of Connecticut has also installed a newly operational automated flood warning system.

Since the primary flood threat on the Thames River estuary is from tidal flooding, the discussion of warnings will emphasize this area. The National Weather Service (NWS) provides public forecasting of imminent natural events. In terms of tidal flooding, flood watch and flood warnings will be forecast and broadcast for minor flooding (up to 2 feet above normal), major flooding and hurricane and storm surge.

Lead time is an important factor with forecasts 12 hours or more in advance usually called a "watch", whereas within 12 hours a warning may be given. The watch alerts residents to the potential of the hurricane and suggests that they should monitor the approaching storm and begin preparations. The second phase of the storm warning process involves the issuance of a "warning" for a large geographical area.

While expected tide heights may be similar at different locations, the differences in timing are significant. In Long Island Sound tides lag by several hours over a relatively few miles. However, the NWS feels that they can advise for hurricane and northeast storm conditions for the Thames River estuary area.

Individual Flood Preparedness Actions. Severe flooding has not been a frequent occurance in Thamesville - the last major flood was in 1955. Under such conditions it is easy for flood plain occupants to get lulled into a false sense of security. While this attitude may exist to some degree, everyone in the area recognizes the flood potential and takes some sort of precautionary action in response to flood warnings. In the case of hurricane "Gloria" in September 1985, nearly all businesses either had their employees not report to work or sent them home early. In addition, the following actions were taken by some of the businesses:

Norwich Iron and Metal. Moved all trucks and cars off site. Sandbagged concrete block building housing the company office.

United Metal of Connecticut. Moved stock from lowest to higher level in building.

Lehigh Petroleum. Moved all trucks and cars off site.

Sawyer Displays. Dedicated the lowest level of building to low intensity use. Located offices, shops and major storage to upper level.

General Dynamics. (Lease space from Sawyer). Relocated stock from ground floor to upper floors.

Dahl Oil. Moved all trucks off site. Oil storage tanks are located out of flood plain.

Connecticut Beverage Co. Moved high value stock (liquors) out of flood plain. Moved trucks and cars off site.

Lehigh Gas. Moved trucks off site. Removed over $50,000 worth of new appliances. Anchored large propane tanks.

SECTION III
PLAN FORMULATION

PROTECTION MEASURES

The basic objective of the study was to determine the best tidal flood damage reduction plan for Thamesville. Alternative flood management measures, both structural and nonstructural, were identified and evaluated to meet this objective. Structural measures are those which prevent flood damages by controlling or modifying floodwaters. Non-structural measures are defined as those which reduce or avoid flood damages without significantly altering the nature or extent of flooding. Applicable measures are:

Structural	Nonstructural
Floodwalls	Flood Warning and Evacuation
Dikes	Permanent Relocation
	Floodproofing

Floodwall/Dike. Structural protection for Thamesville is realistically limited to a concrete floodwall and/or earth dike. Previous studies, including the reconnaissance phase of this study, developed the dike concept. This phase of the study subsequently analyzed a concrete floodwall. The primary advantage for the wall is the smaller space requirement. The corridor between the buildings and river varies from 25 to 200 feet. The wall is required in the tighter spaces and desirable at the wider points to allow adequate space for unimpeded operation of businesses.

Flood Warning and Evacuation. Flood forecasting, warning and evacuation is a strategy to reduce flood losses by charting out a plan of action to respond to a flood threat. The strategy includes:

- A system for early recognition and evaluation of potential floods.
- Procedures for issuance and dissemination of a flood warning.
- Arrangements for temporary evacuation of people and property.
- Provisions for installation of temporary protective measures.
- A means to maintain vital services.
- A plan for postflood reoccupation and economic recovery of the flooded area.

Flood preparedness planning must take place prior to an actual flood, and should facilitate early recognition of the event as well as organize and make more effective a municipality's response. If there has been no flood preparedness planning, then emergency response activities can only be limited.

A flood emergency preparedness system consists of nonstructural measures to reduce risk to life and potential flood damages. The plan consists of two phases:

> Warning, which includes flood threat recognition and flood warning dissemination.
>
> Response, which includes emergency response actions, post-flood recovery and continued plan management.

A major distinction between the two phases can be made in terms of responsibility. The Warning Phase requires regional involvement, while implementation of the Response Phase is mainly a municipal responsibility with state support.

Flood warning is the critical link between forecast and response. An effective warning process will communicate the current and projected flood threat, reach all persons affected, account for the activities of the community at the time of the threat (day, night, weekday, weekend) and motivate persons to action. The decision to warn must be made by responsible agencies and officials in a competent manner to maintain the credibility of future warnings.

Flood insurance. While not a damage reduction measure, flood insurance is also available for buildings and their contents. The city of Norwich is enrolled in the Federal National Flood Insurance Program which enables property owners to purchase flood insurance. The program is based on an agreement between local communities and the Federal government, such that if a community will implement qualified programs to reduce future flood risks, then the Federal government will make subsidized flood insurance available as financial protection against any flood loss.

Floodproofing. This has also been considered and is defined as any combination of structural changes or adjustments incorporated into individual buildings, structures or properties for the reduction of flood damages. The concept is to keep floodwaters away from damageable property or by making the property less susceptible to damage if it is flooded.

Some of the more common floodproofing methods include: raising buildings on fill or columns, constructing walls or dikes around individual properties, installing shields on openings, sealing cracks to keep building interiors dry, and wet floodproofing which allows buildings to flood, but reduces damages by raising equipment and utilities or using flood resistant materials. Keeping water out of buildings through flood shields or blocking is not feasible in the Thamesville area because existing buildings are not designed or constructed to withstand the hydrostatic pressure associated with the potential flood stages. Floodproofing, is not a practical solution to the flood problem at Thamesville due to the high cost of building reinforcement or reconstruction and minimal benefits.

Permanent Relocation. Relocation of flood prone buildings was considered at the request of the city of Norwich. The estimated industrial market values of all properties between the railroad and the river exceed $5 million. An in-depth study at substantial cost would be required for each business to be relocated to determine whether or not there would be compatible areas available to accommodate the individual businesses. Relocation costs would include land, buildings and moving. In addition, it is not practical to relocate the Lehigh Oil tank farm and terminal facilities and the Dahl Oil Company terminal facilities since they depend on proximity to the Thames River for barge deliveries. It would also not be practical to relocate the two multi-story buildings housing Sawyer Displays and American Thermos as both firms make only limited use of their lower floors. These four businesses alone account for most of the benefits which would be realized from relocation. Consequently, relocation is not a feasible flood damage reduction alternative.

In addition to the above flood control measures channel modification of the Thames River and additional upstream flood control reservoirs were evaluated. However, they would have very little effect since flooding at Thamesville is primarily due to tidal surge.

LEVEL OF PROTECTION

Level of protection is defined as the flood level at which residual flood damages and other adverse effects not eliminated by the project are considered relatively minor. Structural flood damage reduction plans are formulated for a level of protection that provides an acceptable degree of risk to health, life and safety.

For nonstructural flood damage reduction plans there is no minimum level of protection. Plans that would leave occupied buildings inaccessible during a flood are normally not recommended.

The following flood event/water elevation relationships were referred to in selecting levels of protection to be evaluated.

Flood Event		Water Elevation (feet NGVD)
2 yr flood	(50% chance of being equaled or exceeded in any given year)	6.0
10 yr flood	(10% chance of being equaled or exceeded in any given year)	8.7
20 yr flood	(5% chance of being equaled or exceeded in any given year)	10.0
100 yr flood	(1% chance of being equaled or exceeded in any given year)	13.4
1938 flood		14.5
Standard Project Hurricane		20.7

(Flood damage begins at elevation 6.0 feet NGVD).

The approach to evaluation of alternatives was to identify plans which would give a range of levels of protection. Past studies formulated a dike plan to the Standard Project Hurricane (SPH) level. Because local interests rejected this expensive, marginally economic, and very high dike, it was decided to not reevaluate this concept. Also, SPH protection would be called for only if overtopping would produce a catastrophe. This would not be likely, since the area is primarily nonresidential, limited in size (35 acres), and very easy to evacuate. Therefore, two lower flood levels were selected:

1. 20 year or 5% flood event - to provide a moderate level of protection with a wall that would be six to seven feet high.

2. 100 year or 1% flood event - to provide a high level of protection with a wall that would be about ten feet high. When freeboard is added to the 100 year level, protection against the observed 1938 flood of record is attained.

Freeboard is the vertical height between the design water surface and the design grade of the flood damage prevention project. A freeboard allowance of three feet was added to the water elevation for each alternative to allow for uncertainties caused by wind and wave run-up.

The design grade of protection is based on the elevation of the water surface. The additional three feet of freeboard increases the project height to design grade. Benefits are estimated up to the mid-point level of the freeboard allowance.

SECTION IV
ALTERNATIVE PLANS

ALTERNATIVE 1 - FLOOD WARNING AND EVACUATION

There are currently flood warning and evacuation actions in effect. While some damage reduction results, there is potential to achieve greater reductions.

The National Weather Service (NWS) retains primary responsibility for detecting and monitoring storms, and tidal flood warning. In the case of hurricanes, the National Hurricane Center (NHC) has this responsibility and forwards information to local NWS offices. Current procedures are the basis upon which the emergency evacuation plan is built. Advisory bulletins are disseminated to these offices at six-hour intervals. When the eye of a hurricane approaches landfall, the reporting interval may decrease to three hours or less if needed. Information in these advisories includes location, direction, tidal surge, characteristics of the storm, forecasts and recommendations concerning public evacuation. Existing riverine automated flood warning systems are the NWS ALERT and State of Connecticut ASERT systems.

According to a State report, estimated initial costs of a minimal coastal monitoring network that measures only tides and storm surge and makes maximum use of existing instrumentation is $51,000. This assumes utilization of some existing radio repeaters and base station components of the Connecticut ASERT system and existing recording tide gages. This cost includes modifying the four existing gages to interface with an ASERT compatible transmitter, in addition to water level strain gage pressure sensors at three new gages, as recommended by the State. Each gaging station would be equipped with water level and meterological sensors, and ASERT compatible encoding and radio transmission instruments.

It makes a difference when a tidal storm surge occurs in terms of final stages attained and flood damages incurred. At Norwich the mean tide range, the difference between mean high and mean low water, is over three feet. A ten foot tidal surge on a normal high tide of three feet results in a 100 year flood. There are also cyclic variations in the stages of high tides of nearly two feet.

The NWS monitors and predicts storm movement and effects and provides this information to the public and emergency management agencies. Flood damage reduction then results through the development and implementation of a flood response plan. As previously discussed, individual businesses have begun this effort to reduce their exposure. However, there can be further reduction in damages through the following actions categorized into two groups by time frame: 1) preparatory actions, and 2) emergency actions, which are further broken down into actions taken upon a storm or flood watch, and actions taken upon a flood warning.

Preparatory Actions

- Identify potential flood stages and flood hazard areas from flood plain maps and elevations of ground and first floors.
- Identify all property and prioritize for removal by value, evacuation time and evacuation methods.
- Identify areas for storage and shelter.
- Identify evacuation routes.
- Arrange for transportation by company vehicles, leased trucks or moving company.
- Prepare written evacuation plans.
- Prepare material for removal, i.e. pallets, boxes, containers.
- Instruct employees (industrial) and family (residential).

Alert Phase. Standard operating procedures for coastal storms and hurricanes at Norwich, Connecticut.

Conditions	Procedural Actions/Duties
NWS announces a storm threat to southern New England	City of Norwich Civil Defense - . Alert flood plain residents and businesses. . Keep informed of developing conditions. Flood Plain Occupants - . Refer to Emergency Response Plan. . Keep informed of developing conditions.

Emergency Actions

Flood Watch

- Review evacuation plans and update as needed.
- Notify employees or family members as applicable.
- Check tide tables.
- Assure operation capability of needed machinery and vehicles.
- Assure availability of needed trucks, manpower, moving companies, storage, shelter.

Flood Warning

- Implement Emergency Response Plan.
- Listen for flood warning updates.
- Check tide tables for time and stage of high tide.
- Evacuate all "non-essential" personnel.
- Remove all vehicles from floodplain.
- Remove or raise stock, records, furnishings, equipment, etc. according to priority established.
- Switch off electrical service, shut fuel cutoffs.
- Assure all anchorages are in place.

In summary, flood emergency preparedness consists of the following two phases:

FLOOD WARNING PHASE

Flood Threat Recognition - procedures and methods for predicting the likelihood of a flood including observation of weather conditions, collection and transmission of data, and interpretation and forecasting.

Flood Warning Dissemination - procedures for deciding to formulate, disseminate and finally send out a warning message to an intended audience.

FLOOD RESPONSE PHASE

Emergency Response Actions - activities undertaken to mitigate and eliminate dangers to health and safety, including flood fighting, traffic control, utility management, maintenance of vital services, and evacuation or movement of persons and material.

Post-Flood Recovery - activities necessary to return flood impacted areas to normal including maintenance of public health, return of services, rehabilitation and repair, and mobilization of assistance.

Continued Plan Management - procedures and activities necessary to maintain the plan as current including plan updating, upgrading and testing.

Economics. This flood warning and evacuation alternative would entail estimated capital investment costs of $51,000 for tidal monitoring equipment, plus containers and pallets for stock. Annual costs are estimated at $23,000 to cover such items as updating plans, training and average costs for actual evacuation of stock and equipment. Annual benefits have been estimated at $192,000 which represents a 23 percent reduction in damages. This results in net benefits of $169,000 and a benefit to cost ratio (BCR) of 8.4. A detailed discussion of benefits and costs is contained in Appendix 4 - Economic Analysis.

ALTERNATIVE 2 - CLUSTER FLOODWALL

The concept of the cluster floodwall (see Figure 3) grew out of the formulation of floodproofing measures for businesses through individual ring walls. Because of the close proximity of Lehigh Oil, United Metal, American Thermos and Sawyer Displays, a wall around the entire cluster was a more logical approach. It was also judged that this wall would actually be characteristic of a structural floodwall rather than a floodproofing measure because of its extent.

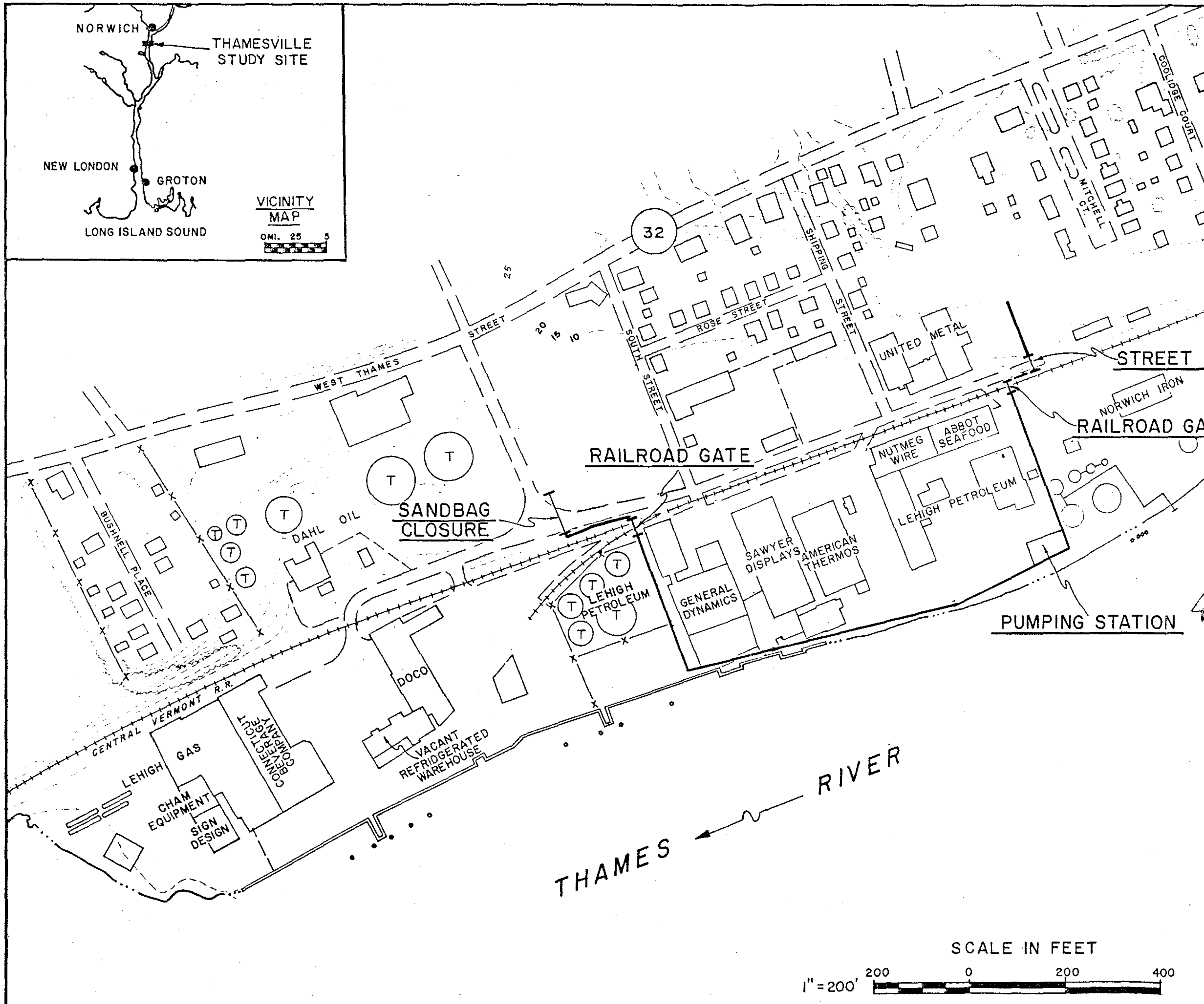
The floodwalls were evaluated for two levels of protection: the 20 year or 5% annual flood event (design water surface elevation or WSEL of 13.0 feet NGVD) and the 100 year or 1% annual flood event (design WSEL of 16.4 feet NGVD). These elevations include three feet of freeboard. The intent here was to evaluate a second less imposing wall in addition to the ten foot wall needed for 100 year protection, which is recommended by State of Connecticut policy unless a plan with move favorable economics exists. The 20 year level of protection has a greater chance of overtopping, however it displays more favorable economics.

Economics. The investment costs for the 20 year (5% annual flood event) and 100 year (1% annual flood event) cluster flood walls and associated nonstructural measures are $4,656,000 and $6,311,000 respectively. A detailed cost analysis is contained in Appendix 3 - Design & Cost Estimates. Annual costs and benefits are given below:

	5% annual flood event	1% annual flood event
Annual Cost	$411,000	$557,000
Annual Benefit	$546,000	$660,000
Net Benefit	$135,000	$103,000
BCR	1.3	1.2

ALTERNATIVE 3 - FULL FLOODWALL

The concept of a concrete floodwall providing protection to the entire area (see Figure 4) was evaluated in the Long Island Sound Regional Study. The floodwall was selected over a dike due to less impact on the river and the narrow strip of land which lies between the buildings and the river.



LONG ISLAND SOUND
TIDAL FLOOD MANAGEMENT STUDY
20 YR./100 YR.
CLUSTER FLOODWALL
THAMESVILLE NORWICH, CT.

NEW ENGLAND DIVISION
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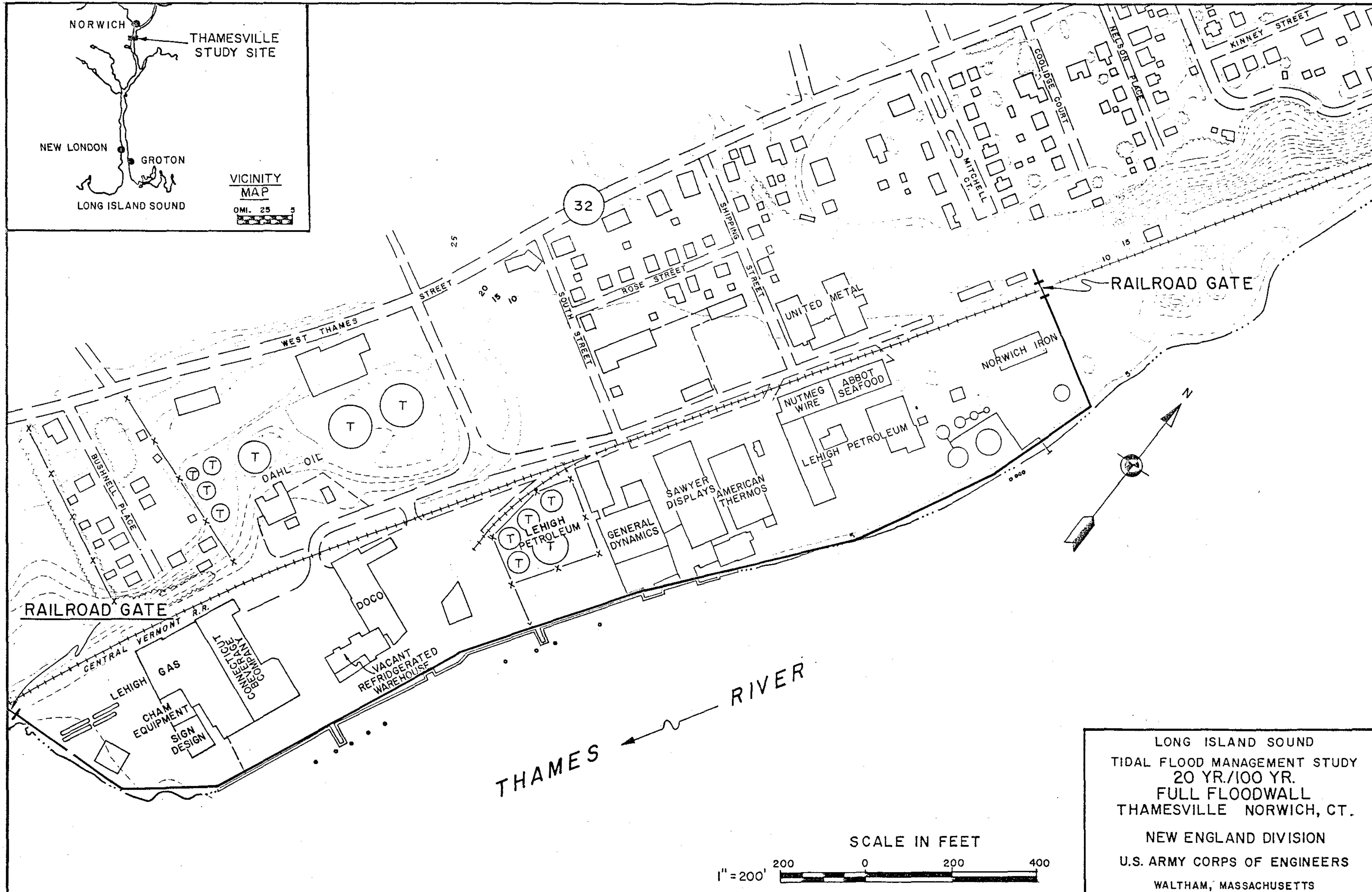


LONG ISLAND SOUND
TIDAL FLOOD MANAGEMENT STUDY
20 YR./100 YR.
FULL FLOODWALL
THAMESVILLE NORWICH, CT.

NEW ENGLAND DIVISION
U.S. ARMY CORPS OF ENGINEERS
WALTHAM, MASSACHUSETTS

FIGURE 4

Economics. The investment cost annual of the full floodwall at the 20 year (5% annual flood event) and 100 year (1% annual flood event) design levels is $7,247,000 and $9,495,000 respectively. See Appendix 3 - Design & Cost Estimates for a detailed breakdown of costs. Annual costs and benefits are listed below:

	5% annual flood event	1% annual flood event
Annual Cost	$647,000	$844,000
Annual Benefit	$625,000	$788,000
Net Benefits (negative)	- $22,000	- $56,000
BCR	0.97	0.93

COMPARISON OF ALTERNATIVES

The study evaluated three different alternatives, with a variation of floodwall height for the two floodwall configurations. The features and differences between these alternatives are presented in the following table.

Net Benefits. Alternative 1, flood warning and evacuation, maximizes annual net annual benefits ($169,000). Alternative 2A, cluster floodwall with 20 year (5% annual flood event) level of protection, closely follows ($135,000). Alternative 3, the full floodwall, is marginally infeasible.

Level of Protection. Evacuation plans would provide full protection to relocated goods and equipment, but no protection for structures. Floodwalls at elevation 16.4 feet NGVD provide protection against the flood of record. It can be assumed that the floodwalls at elevation 13.4 feet NGVD will be overtopped at a more frequent interval. The State of Connecticut recommends a 100 year (1% annual flood event) level of protection, (16.4 feet NGVD) unless there is a more cost effective project. In the event of a standard project hurricane all floodwall plans would be overtopped and major flooding would occur.

Environmental Impacts. The study area is presently a fully developed heavy industrial and commercial area. The alternatives that have been evaluated are not expected to result in significant impacts. The alternatives involving floodwall construction would require river bank slope protection which would encroach into the western edge of the river.

PUBLIC INVOLVEMENT

Extensive public coordination with the City of Norwich, State of Connecticut and the individual property owners has taken place during this study. Various alternative flood damage reduction alternatives have been discussed and evaluated, however nonstructural solutions have been emphasized by the State and more generally accepted due to the much lower cost. Business in the project are have had relatively little interest in the study. They have accepted the flood risk, some have flood insurance and most take remedial action to move stock and equipment when a flood is forcast. Consequently, Alternative 1 is preferred.

TABLE 1
COMPARISON OF ALTERNATIVES

Alternative Number / Primary Measures	1 Floodwarning and Evacuation	2A Cluster Floodwall (20 Year or 5% annual flood event)	2B Cluster Floodwall (100 Year or 1% annual flood event)	3A Full Floodwall (20 Year or 5% annual flood event)	3B Full Floodwall (100 Year or 1% annual flood event)
Economics					
Investment Cost	$51,000	$4,656,000	$6,311,000	$7,247,000	$9,495,000
Annual Cost	23,000	411,000	557,000	647,000	844,000
Annual Benefits	192,000	546,000	660,000	625,000	788,000
Net Annual Benefits	169,000	135,000	103,000	-22,000	-56,000
Benefit: Cost	8.4	1.3	1.2	0.97	0.93
Environmental Impacts					
Aquatic Ecosystem	none	modify river bank	modify river bank	modify river bank	modify river bank
Terrestrial Ecosystem	none	none	none	none	potential increased development of protected area
Visual	none	7-ft wall	10-ft wall	7-ft wall	10-ft wall
Socioeconomic Impacts					
Construction Duration	6 months	2 years	2 years	3 years	3 years
Land Use	none	none	possible redevelopment inside wall	none	possible redevelopment inside wall
Cultural	none	protect structures	protect structures	protect structures	protect structures
Cost Sharing (Fed/Non-Fed)					
Flood Warning System	0/100	---	---	---	---
Floodwall	---	65/35*	65/35*	65/35*	65/35*
Operation & Maintenance	0/100	0/100	0/100	0/100	0/100

* Non-Fed project sponsor pays 35% of project cost. Credit can be given for value of acquired lands, easements, R-O-W, disposal areas and relocations. In any event, there is a minimum 5% cash up front requirement.

SECTION V
CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

The Reconnaissance Report completed in February 1981 for the Long Island Sound Thamesville Tidal-Flood Management Water Resources Study investigated tidal flooding at the Thamesville section of Norwich, Connecticut. This study has expanded upon the Reconnaissance Report by investigating several alternative ways of protecting property using different combinations of nonstructural and structural techniques for flood damage reduction. The programs and policies described in Alternative 1, Flood Warning and Evacuation, can serve as models for tidal-flood plain management throughout the Connecticut coastal area.

Tidal flooding has been identified as a potential problem in the Thamesville area and preliminary investigations have indicated that the Standard Project Hurricane would cause significant damage. Various levels of protection for Thamesville are economically feasible as discussed under nonstructural and structural measures. The least expensive alternative flood management plan also provides the greatest net benefits, and is a nonstructural measure which doesn't require an additional study.

RECOMMENDATIONS

Due to the lack of support by the State and local interests for a marginally feasible and expensive structural flood control solution, Alternative 1, Flood Warning and Evacuation, is recommended to reduce tidal flood damages in Thamesville. Since non-Federal interests have plans to implement this relatively inexpensive system, Federal participation is not required.

It is recommended that non-Federal interests in coordination with the National Weather Service and the Federal Emergency Management Agency, insure the development of comprehensive flood response procedures at the local level for Thamesville; develop and organize a public information and educational program to inform residents of flood-prone areas on "what to do" in the event of a flood emergency; and coordinate on a regular basis to insure operability of all equipment and effectiveness of the response system.

ACKNOWLEDGEMENTS

This report was completed under the supervision of Arthur F. Doyle, Chief, Comprehensive River Basin Section, Donald W. Martin, Chief, Basin Management Branch and Joseph L. Ignasio, Chief, Planning Division. It was prepared by Dennis Waskiewicz and Douglas A. Clevland, Project Managers, with the assistance of the following study team members; Mary A. Donovan - Engineering Design, Ruth M. Kitowitz - Structural Engineering Analysis, Charles H. Wener and Debra A. Strickland - Hydrology, Charles L. Joyce - Economics, Joseph L. Horowitz - Environmental Impacts, Paul Schimelfenyg - Geotechnical Considerations, Edward J. Fallon - Real Estate, John Wilson - Archealogical Analysis and Robert W. Mirick - Flood Warning Systems.

The New England Division would also like to express its appreciation for the cooperation and assistance rendered by the State of Connecticut, Department of Environmental Protection, and the city of Norwich, Planning Department.

SECTION VI

APPENDICIES

APPENDIX 1

TIDAL HYDROLOGY

THAMESVILLE COASTAL FLOOD PROTECTION STUDY
NORWICH, CONNECTICUT
TIDAL HYDROLOGY

1. INTRODUCTION

a. General. The purpose of this report is to provide information relative to the causes, history and frequency of flooding which is needed to evaluate flood protection measures for the Thamesville area of Norwich, Connecticut. Factors related to the types of storms affecting the area as well as normal and storm tides will be discussed.

b. Description of Study Area. The city of Norwich is located at the headwaters of the Thames River estuary in the southeastern portion of Connecticut in north-central New London County. Norwich is bordered by Sprague on the north, Franklin and Bozrah on the west, Lisbon and Preston on the east, and Montville on the south. New London is 12 miles to the south, downstream at the mouth of the Thames River estuary.

Thamesville, one of three settlements in Norwich, is composed of a cluster of industrial plants located along a narrow level shelf formed along the westerly bank of the Thames River and a cluster of residential properties located around the intersection of Dunham and West Thames Streets. Conrail passes along the inner edge of this shelf. Thamesville lies approximately 0.7 mile downstream from the confluence of the Yantic and Shetucket Rivers, the upper limit of the Thames River estuary (see figure 1).

A tidal estuary, the Thames River drains a watershed of 1,382 square miles at the southern corporate limit of Norwich. The drainage basin includes a major portion of eastern Connecticut and portions of western Rhode Island and southern Massachusetts. Six Corps of Engineers flood control reservoirs affect riverine flows on the Thames River: Mansfield Hollow (1952), Buffumville (1958), Hodges Village (1959), East Brimfield (1960), Westville (1962), and West Thompson (1965). Subject to mean tidal fluctuations of 2.6 feet at New London Harbor and 3.1 feet at Norwich, the river is maintained as a navigable channel (25 foot depth) from Long Island Sound at New London northward to Norwich. Norwich's tidal shoreline along the west bank of the Thames River, below the junction of the two rivers, is about 2.7 miles long, and the east bank is about 3.4 miles long; a total shoreline of 6.1 miles.

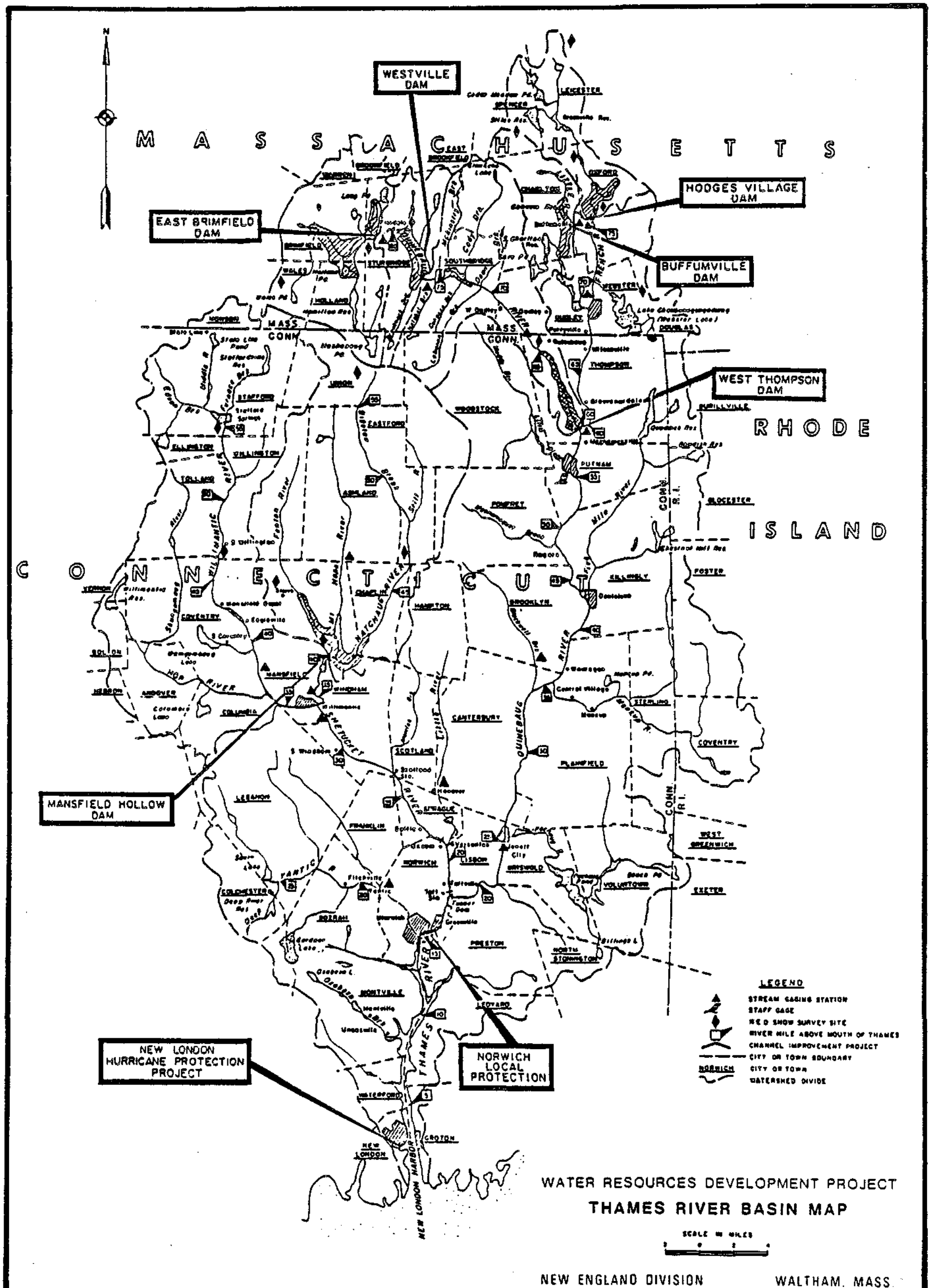

MASSACHUSETTS
CONNECTICUT
RHODE ISLAND
WESTVILLE DAM
EAST BRIMFIELD DAM
HODGES VILLAGE DAM
BUFFUMVILLE DAM
WEST THOMPSON DAM
MANSFIELD HOLLOW DAM
NEW LONDON HURRICANE PROTECTION PROJECT
NORWICH LOCAL PROTECTION
LEGEND
STREAM GAGING STATION
STAFF GAGE
SNOW SURVEY SITE
RIVER MILE ABOVE MOUTH OF THAMES
CHANNEL IMPROVEMENT PROJECT
CITY OR TOWN BOUNDARY
CITY OR TOWN
WATERSHED DIVIDE
WATER RESOURCES DEVELOPMENT PROJECT
THAMES RIVER BASIN MAP
SCALE IN MILES
NEW ENGLAND DIVISION
WALTHAM, MASS.

FIGURE 1

In the low-lying Thamesville study area there are approximately 42 structures consisting of 10 residential, 12 commercial, 8 industrial and 12 large storage tanks. These businesses (on the 36-acre site) include bottled gas, wholesale produce, display designers and producers, two large oil companies, a large scrap metals company, and warehousing for picnic supplies, seafood and beverages (see plates 1a and 1b).

2. NORMAL HYDROLOGIC CONDITIONS

a. Climatology. The variable temperature climate of the Thames River basin is typical of lower coastal New England and its latitude. Four distinct seasons are observed; however, long periods of extreme hot or cold weather are rare for two reasons. Firstly, Long Island Sound and the Atlantic Ocean provide a moderating influence. Secondly, the irregular movements of high and low pressure systems approaching from the west or southwest cause frequent weather changes of varying intensity. In the winter, coastal storms usually bring rainfall, in contrast to snow in the more northerly area of Connecticut. Sea breezes from the south, thunderstorms from the west, and cool air from the north are experienced in the summer. The prevailing winds are northwesterly in the winter and southwesterly in the summer. Short periods of heavy precipitation are characteristic and, like high winds and abnormally high tides, occur with uncertain frequency. Hurricanes are a threat especially during August, September and October.

Hydrometeorological records at Groton, Connecticut are representative of Norwich. The observed maximum, minimum and mean annual temperatures are 99, -14 and 45 degrees Fahrenheit, respectively. The average annual precipitation is about 47 inches and the average annual depth of snow is approximately 44 inches.

b. Astronomical Tides.

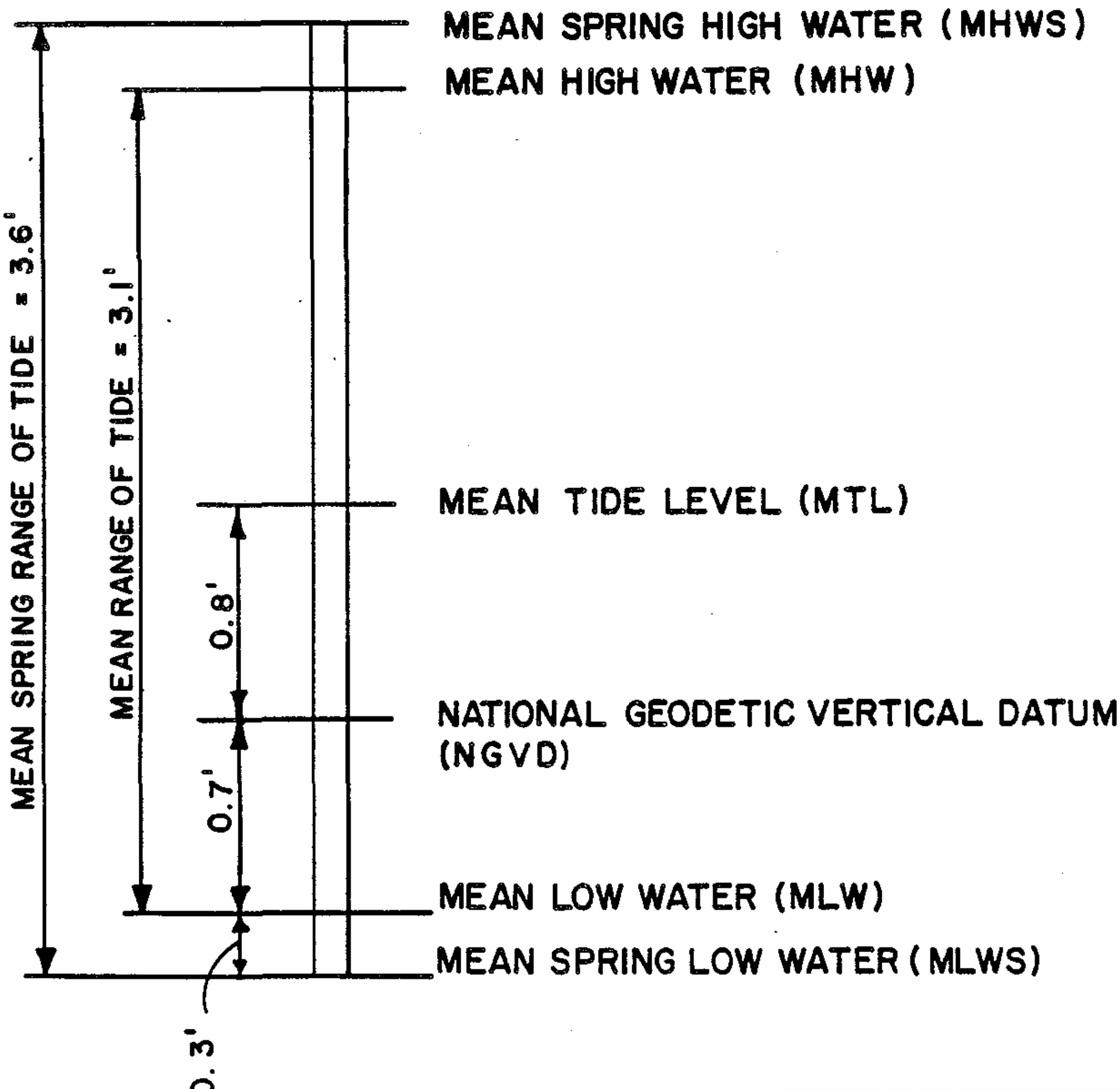
(1) Tide Range. At Norwich tides are semidiurnal, with two high and two low waters occurring during each lunar day (approximately 24 hours and 50 minutes). The resulting tide range is constantly varying in response to the relative positions of the earth, moon, and sun; the moon having the primary tide producing effect. Maximum tide ranges occur when the orbital cycles of these bodies are in phase. A complete sequence of tide ranges is approximately repeated over an interval of 19 years, which is known as a tidal epoch. The mean range of tide and the mean spring range of tide are 3.1 feet and 3.6 feet, respectively (see figure 2). However, the maximum and minimum probable astronomic tide

FIGURE 2

TIDAL DATUM PLANES

NORWICH, CONNECTICUT

(APPROXIMATE VALUES BASED UPON CURRENTLY AVAILABLE, SHORT TERM, NATIONAL OCEAN SURVEY TIDAL BENCHMARK DATA OBSERVED AT NORWICH AND NEW LONDON)



NEW ENGLAND DIVISION
U.S. ARMY, CORPS OF ENGINEERS
WALTHAM, MASS. DEC. 1985

ranges have been estimated at about 5.4 and 0.6 feet, respectively, using the Coastal Engineering Research Center's (CERC) report entitled "Tides and Tidal Datums in the United States", SR No. 7, 1981 (see table 1). The variability of astronomical tide ranges is a significant factor in tidal flooding potential at Norwich.

(2) Tidal Datums. Because of the continual variation in water level due to the tides, several reference planes, called tidal datums, have been defined to serve as a reference zero for measuring elevations of both land and water. Tidal datum information for Norwich is presented on figure 2 and table 1. These data were compiled using currently available short term National Ocean Survey (NOS) tidal benchmark data for Norwich and New London along with the CERC report SR No. 7.

TABLE 1

NORWICH
TIDAL DATUM PLANES

	Tide Level (ft. NGVD)
Maximum Probable Astronomic High Water	3.5
Mean Spring High Water (MHWS)	2.6
Mean High Water (MHW)	2.4
Minimum Probable Astronomic High Water	1.1
Mean Tide Level (MTL)	0.8
Maximum Probable Astronomic Low Water	0.5
National Geodetic Vertical Datum (NGVD)	0.0
Mean Low Water (MLW)	-0.7
Mean Spring Low Water (MLWS)	-1.0
Minimum Probable Astronomic Low Water	-1.9

(3) Rising Sea Level. A phenomenon that has been observed through tide gaging and tidal benchmark measurements is that sea level is apparently rising with respect to the land along most of the US coast. At Norwich, the rise is estimated to be slightly less than 0.1 foot per decade. Sea level determination is generally revised at intervals of 25 years to account for the changing sea level phenomenon. The NOS is presently engaged in the process of reducing tide

data from the 1960-1978 tidal datum epoch to make such a revision.

(4) Other Factors Influencing Tides. The tides are subject to meteorological influences such as changes in atmospheric pressure and strong winds besides the normal gravitational effects of the sun and moon. A drop in barometric pressure of 1 inch of mercury will cause about a 1-foot rise in water levels. During coastal storms tide levels often build up several feet above predicted elevations due to combined wind, wave, and barometric effects.

Tides are also influenced, although to a much lesser degree, by the earth's rotation, which in the Northern Hemisphere produces an acceleration to the east in any ocean or coastal current. A coastal inlet oriented north-south would therefore theoretically experience slightly higher tides on the east shore. Runoff from heavy rainfall associated with a coastal storm can increase water levels in tidal estuaries and, in combination with sea levels, contribute to tidal flooding.

3. STORM TYPES

Two distinct types of storms, distinguished primarily by their place of origin as being either extratropical or tropical cyclones, affect New England coastal areas with high tides, wind and heavy rainfall. These storms must be recognized when studying New England coastal flooding problems.

a. Tropical Cyclones. These storms form with a counterclockwise cyclonic wind circulation in the northern hemisphere over warm tropical ocean water in the Caribbean, Atlantic Ocean and adjacent to the West Coast of Africa. Energy for the storm is provided by the latent heat of condensation. When the windspeed exceeds 75 miles per hour extending outward 50 miles or more from the center, and the storm is accompanied by very low atmospheric pressure, torrential rains, very high waves and high coastal tide surges the tropical cyclone is labeled a hurricane. Another characteristic of a hurricane is a calm center or "eye" which averages about 15 to 20 miles in diameter. Along the edge of the center the strongest winds of the storm spiral and rise into the upper atmosphere thereby releasing significant rainfall from the moisture saturated air mass. Tropical storms which are tropical cyclones with gales to just under hurricane force winds, possess many characteristics of a hurricane but to a lesser degree. Flooding can result from several causes including breaking waves, storm tide surge and torrential rains.

Hurricane winds generate large waves in the open ocean with the ultimate size depending on wind speed and duration, as well as the fetch or distance the waves travel. Ocean waves, while travelling tremendous distances and diminishing in size and strength, may reach distant shores 1 or 2 days in advance of a hurricane and cause damage prior to the onset of the storm proper. As the hurricane waves approach shallow waters, their forward movement is slowed by bottom friction and forced to rise even higher before breaking and dissipating along the shoreline. Driven by hurricane winds, the breaking waves will run up on a beach or overtop vertical structures well above the normal water level, hence reports of wave and flood damage from 5 to 25 feet above stillwater level are not uncommon in open coastal areas. Since Thamesville is well inland in the Thames River estuary, open ocean waves will not be a concern. However, some smaller locally generated waves are possible.

Flooding also results from inundation by the storm tide surge, defined as rise in water surface above the astronomical predicted tide level. The surge is caused by a combination of low barometric pressure, onshore winds, waves and forward movement of the storm. The rate of water level rise also depends upon the forward speed of the approaching storm and whether the natural tide is rising or falling. This is of concern in the Thames estuary where tidal surges in excess of 12 feet have been experienced.

Even though hurricanes and tropical storms are sustained over warm ocean water, they usually retain enough energy while dissipating over cooler water or land to produce excessive rainfall. Rainfall rates of 1 to 2 inches per hour have been recorded over southern New England from tropical storms and hurricanes. Heavy precipitation is likely to occur, not only near the center but also 1 to 3 days in advance of a hurricane.

Recent hurricanes affecting New England's south coastline generally have crossed Long Island Sound and proceeded in a generally northerly direction (see figure 3). However, hurricane tracks can be erratic. The storms lose much of their strength after landfall. For this reason the southern coast of New England experiences the greatest surge and wave action from the strong southerly to southeasterly hurricane winds. The hurricane season in New England generally extends from August through October. Hurricanes are the single most significant cause of catastrophic flooding in the Thamesville area.

b. Extratropical Cyclones. These are the most frequently occurring variety of cyclones in New England. Low pressure centers frequently form or intensify along the boundary between a cold dry continental air mass and a warm moist marine air mass just off the Atlantic coast from Florida to New Jersey and move northeastward more or less parallel to the coast. These storms derive their energy from the temperature contrast between cold and warm air masses. The organized circulation pattern associated with this type of storm may extend for 1,000 to 1,500 miles from the storm center. When these storm centers pass to the west of the Norwich area, the gale winds become southerly and will cause a significant tide surge in the Thames River estuary until the winds shift into the west quadrant. During a coastal storm the highest abnormal tides usually occur within one hour of the time of the predicted high tide. Some coastal storms stall off the southeast coast of New England and produce high tides that persist for several days. The prime season for extratropical storms in New England is November through April. Although causing a more frequent threat to southern New England, flooding does not rival that possible during a hurricane.

4. HISTORIC FLOOD EVENTS

a. Types of Flooding. The upper Thames River estuary is subject to three causes of flooding: tidal, riverine, or a combination of the two. For instance, coastal storms or hurricanes produce tidal flooding. The entire length of the Thames River is affected by tidal fluctuations from its mouth at Long Island Sound to the confluence of the Yantic and Shetucket Rivers. Coastal flooding most frequently has occurred as a result of winds during extratropical storms. However, the highest levels of coastal flooding have occurred coincident with hurricanes.

In addition, intense rainfall generally produces high riverine flows. The major contributor to peak riverine flow at Norwich is the Shetucket River which receives flow from the Quinebaug, Willimantic, and Natchaug Rivers (drainage area equals 1,264 square miles). The fan-shaped Natchaug River basin with three streams, narrow valleys and steep slopes produces the highest rates of runoff. The Yantic River (drainage area of 98 square miles), with minor flood problems within its own basin, does not contribute significantly to inundation at Norwich. Appreciable flooding can also result when high riverine flows occur coincident with tidal flooding. Table 2 shows observed water surface elevations in feet above NGVD at the confluence of the Shetucket and Yantic Rivers, 0.7 mile upstream from Thamesville, for

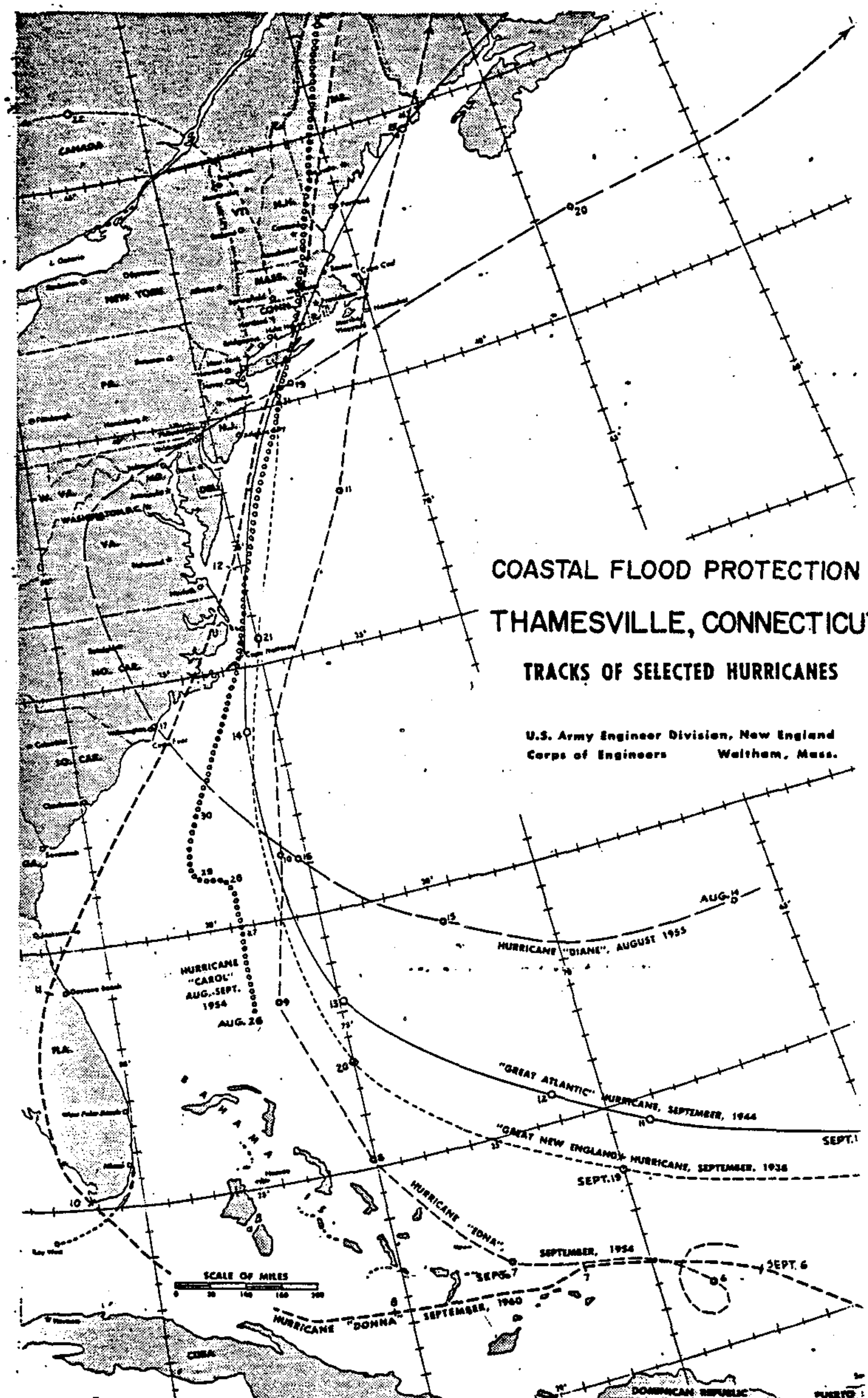

COASTAL FLOOD PROTECTION
THAMESVILLE, CONNECTICUT
TRACKS OF SELECTED HURRICANES
U.S. Army Engineer Division, New England
Corps of Engineers Waltham, Mass.
CANADA
NEW YORK
VT.
N.H.
MASS.
CONN.
PA.
N.J.
DEL.
MD.
W. VA.
WASHINGTON D.C.
VA.
NO. CAR.
SO. CAR.
GA.
FLA.
CUBA
DOMINICAN REPUBLIC
HURRICANE "DIANE", AUGUST 1955
AUG. 14
HURRICANE "CAROL" AUG.-SEPT. 1954
AUG. 26
"GREAT ATLANTIC" HURRICANE, SEPTEMBER, 1944
SEPT. 1
"GREAT NEW ENGLAND" HURRICANE, SEPTEMBER, 1938
SEPT. 19
HURRICANE "EDNA", SEPTEMBER, 1954
SEPT. 6
HURRICANE "DONNA", SEPTEMBER, 1960
SCALE OF MILES

FIGURE 3

three recent hurricane events. Tidal and river flood contributions have also been estimated. The approximate effect of the six flood control reservoirs in the Thames basin is presented in table 3.

TABLE 2

NORWICH, CONNECTICUT
CONFLUENCE OF THE SHETUCKET AND YANTIC RIVERS
EXPERIENCED FLOOD LEVELS

Hurricane Event	Observed Water Surface Elevation (ft,NGVD)	Estimated Contributing Factor		Type of Flooding
		Storm Tide (ft)	River Flood (ft)	
Sep 1938	15	12	3	Combination
Aug 1954	10.5	10.5	0	Tidal
Aug 1955	10.2	0	10.2	Riverine

TABLE 3

NORWICH, CONNECTICUT
CONFLUENCE OF THE SHETUCKET AND YANTIC RIVERS
RECURRENCE WITH FLOOD CONTROL PROJECTS

Hurricane Event	Estimated Water Surface Elevation (ft,NGVD)	Estimated Contributing Factor		Type of Flooding
		Storm Tide (ft)	River Flood (ft)	
Sep 1938	14	12	2	Combination
Aug 1954	10.5	10.5	0	Tidal
Aug 1955	7	0	7	Riverine

This information which was prepared for reservoir regulation purposes shows that the 1938 flood level at the confluence could be about one foot less with Corps reservoirs in place. The effect of riverine flow at Thamesville has not been quantified but would be similar. Tidal surge alone or in combination with high riverine flow is the principal cause of flooding at Thamesville. High flows at normal tide are not expected to be a major problem.

b. Recent Hurricanes. In this century the Thames River has experienced significant floods in September 1938, August 1954, and August 1955. Descriptions of these events are given in the following paragraphs.

(1) September 1938. Damage caused by tidal flooding from this hurricane was the greatest ever experienced in Long Island Sound. The center of the hurricane entered Connecticut perpendicular to the coast about 15 miles east of New Haven on 21 September 1938 and then proceeded northwesterly at a forward speed of 50 to 60 mph. The peak of the hurricane tide arrived about 1 to 2 hours before the predicted normal high tide throughout most of the Sound, causing extreme tide levels. At New London the surge was 9.2 feet and the duration of tidal flooding above the elevation of mean high water was 4.3 hours.

The maximum recorded wind velocity in New England was a gust of 186 mph at the Blue Hills Observatory, Milton, Massachusetts, where a sustained 5-minute wind of 121 mph was also recorded. At other locations along the southern coast, sustained 5-minute velocities ranging from 38 to 82 mph were experienced. The lowest barometric pressure recorded in the area during the storm was 28.4 inches at Hartford, Connecticut.

This event also produced the greatest flood of record along the Shetucket and Natchaug Rivers. Above normal rainfall prior to the storm left many natural storage areas filled and ground water conditions saturated. This condition resulted in serious flooding when 10 to 14 inches of rain associated with the hurricane fell on the basin during 17-21 September. Totals for the storm at Southbridge, Worcester, and Storrs were 13.5, 8.4 and 13.8 inches, respectively. Peak discharges on the Hop River near Columbia, Natchaug River at Willimantic, and Shetucket River at Willimantic were 85, 189 and 130 cubic feet per square mile (csm), respectively. Total volume of runoff at these stations during the period 19-24 September were 7.5, 6.7 and 8.4 inches, respectively.

Consequently, with the coincidence of high tidal flooding and extreme runoff, the record level of flooding at Norwich occurred on 21 September 1938 when the river level rose to 14.5 feet NGVD. The maximum observed at Thamesville was 14.2 feet NGVD.

(2) 31 August 1954 ("Carol"). The second most severe hurricane to strike southern New England in over 100 years occurred just 16 years after the 1938 event. The center of this storm crossed the shoreline of Connecticut near New London with a forward speed of about 45 mph and then followed a general northerly path across New England. As the hurricane surge occurred at or near predicted normal high tide within the Sound, tide levels rose to near record heights. Tidal surges ranged from 5 to 8 feet higher than predicted tides.

The wind attained a maximum gust of 135 mph and a 5-minute sustained velocity of 98 mph at Block Island, Rhode Island. Minimum barometric pressures of 28.2 and 28.3 inches were recorded at Storrs and New London, Connecticut, respectively.

At New London the surge was 7.4 feet and the duration of tidal flooding was 7.7 hours. The abnormal tide levels at Norwich and Thamesville reached 10.5 and 9.9 feet NGVD, respectively. Though this hurricane caused moderate to heavy rainfall in New England, it produced minor flooding on the contributing streams. Consequently this was principally a tidal flooding event.

(3) August 1955. This flood event resulted from hurricane "Diane" which was preceded one week earlier by 3 to 6 inches of rainfall from hurricane "Connie". The earlier storm left many natural storage areas filled and ground water conditions ripe for runoff. Rainfall resulting from hurricane "Diane", between 17-20 August, amounted to 2 inches in coastal areas of the basin with 10 to 16 inches in the headwaters of the Quinebaug, French and Willimantic River watersheds. Rainfall totals for the storm at Putnam, Mansfield and Southbridge amounted to 8.2, 13.0 and 11.7 inches, respectively. Peak discharges of the French River at Webster, Quinebaug River at Quinebaug, and the Quinebaug River at Putnam were 168, 314 and 145 csm, respectively. The volume of runoff passing these gages for the period 19-22 August was 6.7, 11.6 and 11.7 inches, respectively.

Although wind and tidal effects are commonly the principal features of hurricanes, they were minor characteristics with hurricane "Diane". The intense rainfall was the most outstanding feature. Both of these storms took an inland route through the mid-Atlantic States so no significant storm surge occurred during their passage. The band of torrential rains crossed the basins of the principal rivers almost normal to the main stems. Record floods resulted on the Quinebaug and French Rivers. As indicated in table 2, this was a riverine flood event. Flood level at Thamesville is unknown, however it is estimated to be up to one foot lower than that experienced at Norwich (see table 2).

5. STORM TIDES AND TIDE STAGE FREQUENCY

a. General. The total effect of astronomical tide combined with storm surge produced by wind, wave, and atmospheric pressure contributions is reflected in actual tide gage measurements. Since the astronomical tide is so variable at the study area, the time of occurrence of the storm surge greatly affects the magnitude of the resulting tidal flood level. Obviously, a storm surge of three feet occurring at a low astronomic tide would not produce as high a water level as would be produced if it occurred at a higher tide. It is important to note that the storm surge itself varies with time thus introducing another variable into the makeup of the total flood tide at any point in time.

b. Comparison of Extreme High Tides at New London and Thamesville. A listing of maximum observed tide levels at New London is provided in table 4. The table also indicates the elevation that would be attained if the same tidal flood producing event were to occur at 1975 sea level. This listing was developed with recorded tide gage data gathered at New London by the NOS. Of the five greatest tide levels shown, only one was caused by a northeaster. The prevalent type of major flood producing storm affecting this area is the hurricane. Tidal elevations at New London are affected negligibly by flows on the Thames River. However, this is clearly not the case at Norwich (see table 5) where the flooding may be tidal, riverine or a combination of the two. The greatest experienced flood level happened during the September 1938 hurricane event when record high river discharges occurred coincident with record tidal surge. During the 1954 hurricane, flooding was principally tidal. The August 1955 hurricane, which was mainly a riverine flow event, is not known to have produced significant flooding at Thamesville (a staff gage and crest gage were established at Thamesville in 1985).

c. Tidal Flood Frequency. A tide stage-frequency relationship for New London has been developed utilizing a composite of a Pearson Type III distribution function, with expected probability adjustment, for analysis of adjusted annual maximum and historic still water tide levels and a

TABLE 4

NEW LONDON, CONNECTICUT
MAXIMUM OBSERVED TIDE LEVELS
(1938 - 1985)

Date	Observed Still Water Elevation (ft,NGVD)	Adjusted Elevation* (ft,NGVD)
21 Sep 1938**	9.7	10.1
31 Aug 1954** ("Carol")	8.9	9.1
25 Nov 1950	6.7	6.9
14 Sep 1944**	6.2	6.5
12 Sep 1960** ("Donna")	6.0	6.1
7 Nov 1973	5.9	6.1
12 Nov 1968	5.5	5.6
19 Feb 1972	5.2	5.2
19 Dec 1966	5.1	5.2
12 Nov 1947	4.9	5.2
27 Sep 1985** ("Gloria")	5.1	5.1
19 Feb 1960	5.0	5.1
3 Mar 1942	4.7	5.0
4 Mar 1973	4.9	4.9
30 Nov 1944	4.6	4.9
22 Mar 1977	4.8	4.8
25 Dec 1978	4.8	4.8
16 Feb 1958	4.6	4.8
25 Jan 1979	4.7	4.7
2 Dec 1942	4.4	4.7
30 Nov 1963	4.6	4.7
16 Mar 1956	4.5	4.7
20 Mar 1958	4.5	4.7
21 Sep 1961	4.5	4.6
9 Mar 1961	4.5	4.6
7 Mar 1962	4.5	4.6
6 Dec 1962	4.5	4.6
6 Mar 1943	4.2	4.5
12 Dec 1944	4.2	4.5
22 Nov 1945	4.2	4.5

* Observed values after adjustment for rising sea level; adjustment made to 1975 sea level conditions, based on N.O.S. publication "Trends and Variability of Yearly Mean Sea Level, 1893-1973".

** Hurricane

graphical solution of Weibull plot positions for partial duration series data. Using high watermark data from Norwich, a stage correlation with New London was developed. Using this correlation and the New London frequency curve, a tidal flood frequency relationship for Norwich was estimated (figure 4). It should be noted that this correlation included the observed 1938 flood level at Thamesville. Therefore, the modifying effect of upstream Corps reservoirs which may be around one foot during the recurring 1938 event was not included. If a project improvement is recommended for further study, a more detailed analysis of stage frequency should be conducted to better define the effect of upstream reservoirs in reducing flood stages at Thamesville.

TABLE 5

THAMESVILLE, CONNECTICUT
MAXIMUM OBSERVED FLOOD LEVELS

Hurricane	Observed Stillwater Elevation (ft,NGVD)
Sep 1938	14.2
Aug 1954 ("Carol")	10.3
Aug 1955 ("Diane")	Unknown

d. Tidal Flood Profiles. Profiles of major past tidal floods have been developed along the New England coast. NOS tide gage records and high watermark data gathered between gage locations after major storms have been utilized in the development of these profiles. Additionally, profiles of storm tides of selected frequencies have been developed utilizing frequency distributions at tide gages and high watermark information. A vicinity map and flood profile for the Thames River are shown on figure 1 and plate 2, respectively. A base map and tidal flood profile for Long Island Sound at New London are illustrated on plates 3 and 4, respectively.

e. Standard Project Hurricane. Protective structures at Thamesville must be evaluated in terms of residual

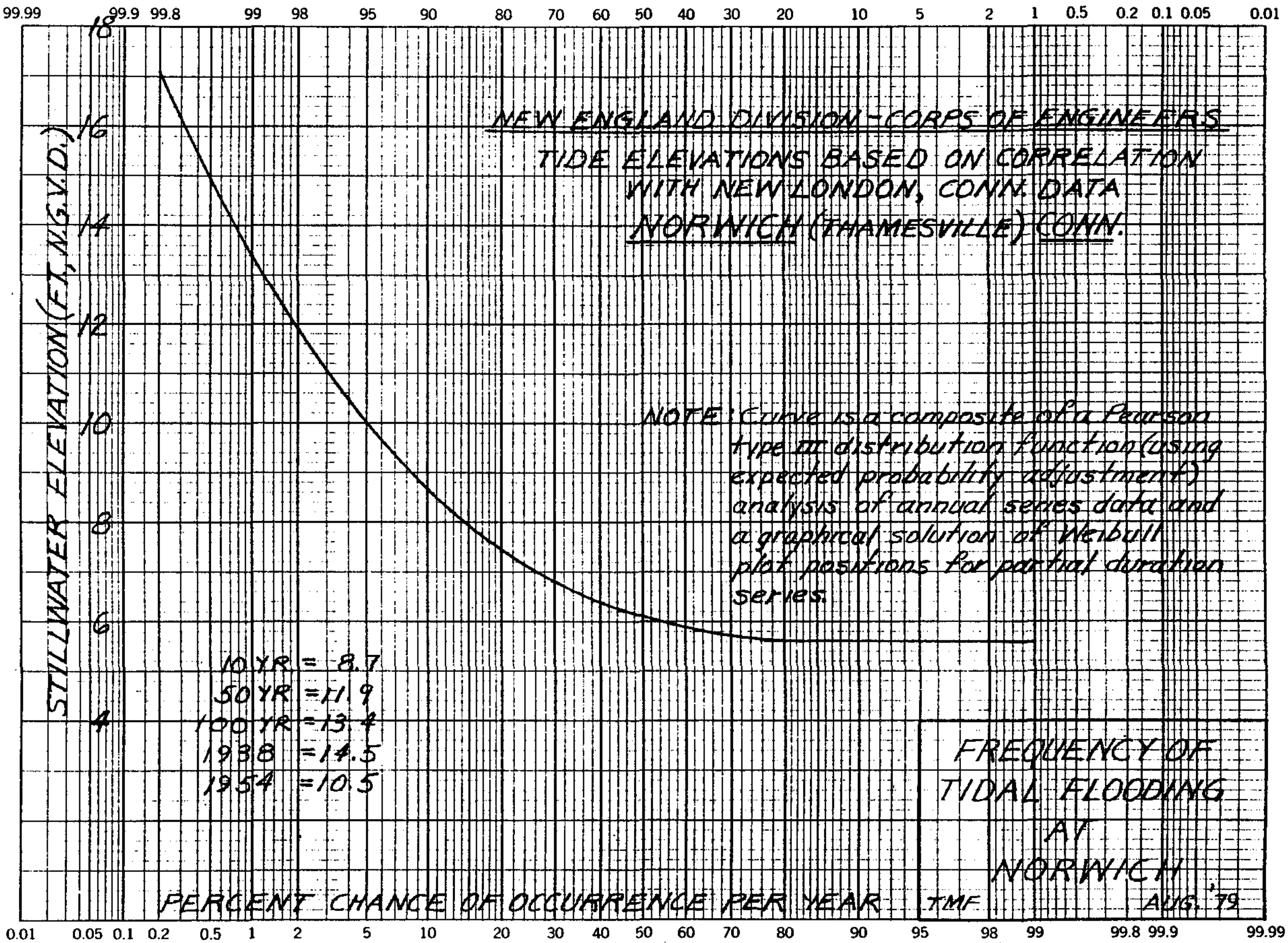

NEW ENGLAND DIVISION - CORPS OF ENGINEERS
TIDE ELEVATIONS BASED ON CORRELATION WITH NEW LONDON, CONN. DATA
NORWICH (THAMESVILLE) CONN.
NOTE: Curve is a composite of a Pearson type III distribution function (using expected probability adjustment) analysis of annual series data and a graphical solution of Weibull plot positions for partial duration series.
10 YR = 8.7
50 YR = 11.9
100 YR = 13.4
1938 = 14.5
1954 = 10.5
STILLWATER ELEVATION (FT. N.G.V.D.)
PERCENT CHANCE OF OCCURRENCE PER YEAR
FREQUENCY OF TIDAL FLOODING AT NORWICH
TMF
AUG. '79
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
0.01 0.05 0.1 0.2 0.5 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
18 16 14 12 10 8 6 4

Figure 4

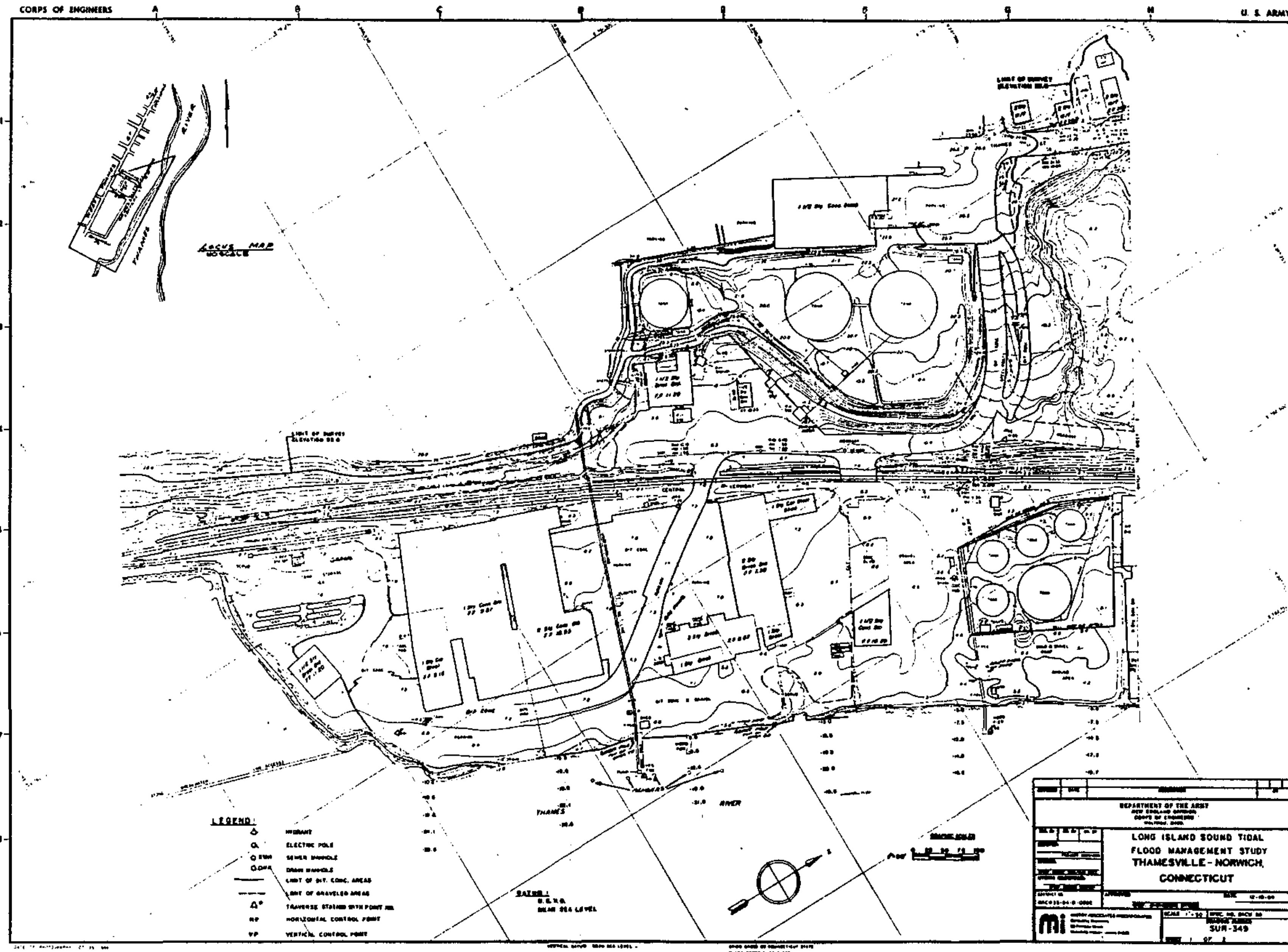
damages which can be expected during the most severe combination of storm tide and wave action that can reasonably be expected. A design hurricane, the "Standard Project Hurricane" (SPH), was established by the U.S. Weather Bureau (now the National Weather Service) and the Beach Erosion Board (now CERC) assisted by the Texas Agricultural and Mechanical Research Foundation. The SPH is representative of the most severe combination of meteorological conditions that are considered reasonably characteristic of the region. A transposition of the September 1944 hurricane was established as the design storm. This storm, when it was off Cape Hatteras, had the greatest energy of any known hurricane along the Atlantic Coast.

The SPH was transposed over an ocean point between Cape Hatteras and the New England coast to simulate the maximum surges along the Connecticut shore line of Long Island Sound. The transposed hurricane was assumed to advance in a due northerly direction at a forward speed of 40 knots (about 46 mph), with its center crossing the New England coast at a point 43 nautical miles (49 statute miles) west of New London, near the eastern entrance to Long Island Sound. The storm track placed the most critical area of the hurricane at the entrance to the Sound, producing the highest surge along the Connecticut coast line, on the north shore of Long Island Sound. Routing this up the Sound gives surges from 9.0 to about 13.0 feet at various locations along the Sound. At New London the design surge is 12.5 feet. The tide curves illustrated on plate 5 are useful when comparing the SPH to the 1938 and 1954 hurricane events.

Adding the resultant surge to the mean spring tide has been designated as the Standard Project Hurricane Flood Level (SPHFL). At Thamesville this elevation is 20.7 feet NGVD, the sum of mean spring tide at Thamesville, the wind setup from New London to Thamesville and the computed SPH surge at Thamesville. The SPH surge was determined by adjusting the SPH surge at New London with the ratio of the hurricane surges at Thamesville and New London on 21 September 1938. As observed 1938 flood levels were used in the derivation, the present SPHFL does not include the effect of upstream reservoirs in reducing flood stages at Thamesville. If a project improvement is approved for further study, the SPHFL should be reanalyzed. The present SPHFL is shown on plate 2.

6. SUMMARY

In the preceding sections, astronomical tides were discussed with emphasis on typical tide levels and data conversions for the study area. Sea level rise relative to the land was mentioned. Meteorological factors including storm types were evaluated. Recorded extreme flood levels at Thamesville were utilized to indicate the combined effect of astronomical tide and storm surge due to wind, wave, and barometric effects on water level. Tidal surge, alone or in combination with a significant runoff event, is the principal cause of flooding. Tidal flood frequency was estimated and tidal flood profiles were presented. This climatic and tidal hydrology information will provide essential background information for evaluation of flood protection at the study area. The staff gage and crest gage now located in the Thamesville area will serve for observed peak water levels in the future.



CORPS OF ENGINEERS
U. S. ARMY
LOCUS MAP
THAMES
RIVER
DATUM:
U.S.G.S.
MEAN SEA LEVEL
LEGEND:
ELECTRIC POLE
SEWER MANHOLE
DRAIN MANHOLE
LIMIT OF BIT. CONC. AREAS
LIMIT OF GRAVELED AREAS
HORIZONTAL CONTROL POINT
VERTICAL CONTROL POINT
DEPARTMENT OF THE ARMY
LONG ISLAND SOUND TIDAL
FLOOD MANAGEMENT STUDY
THAMESVILLE - NORWICH,
CONNECTICUT
SUR-349

Plate 1a

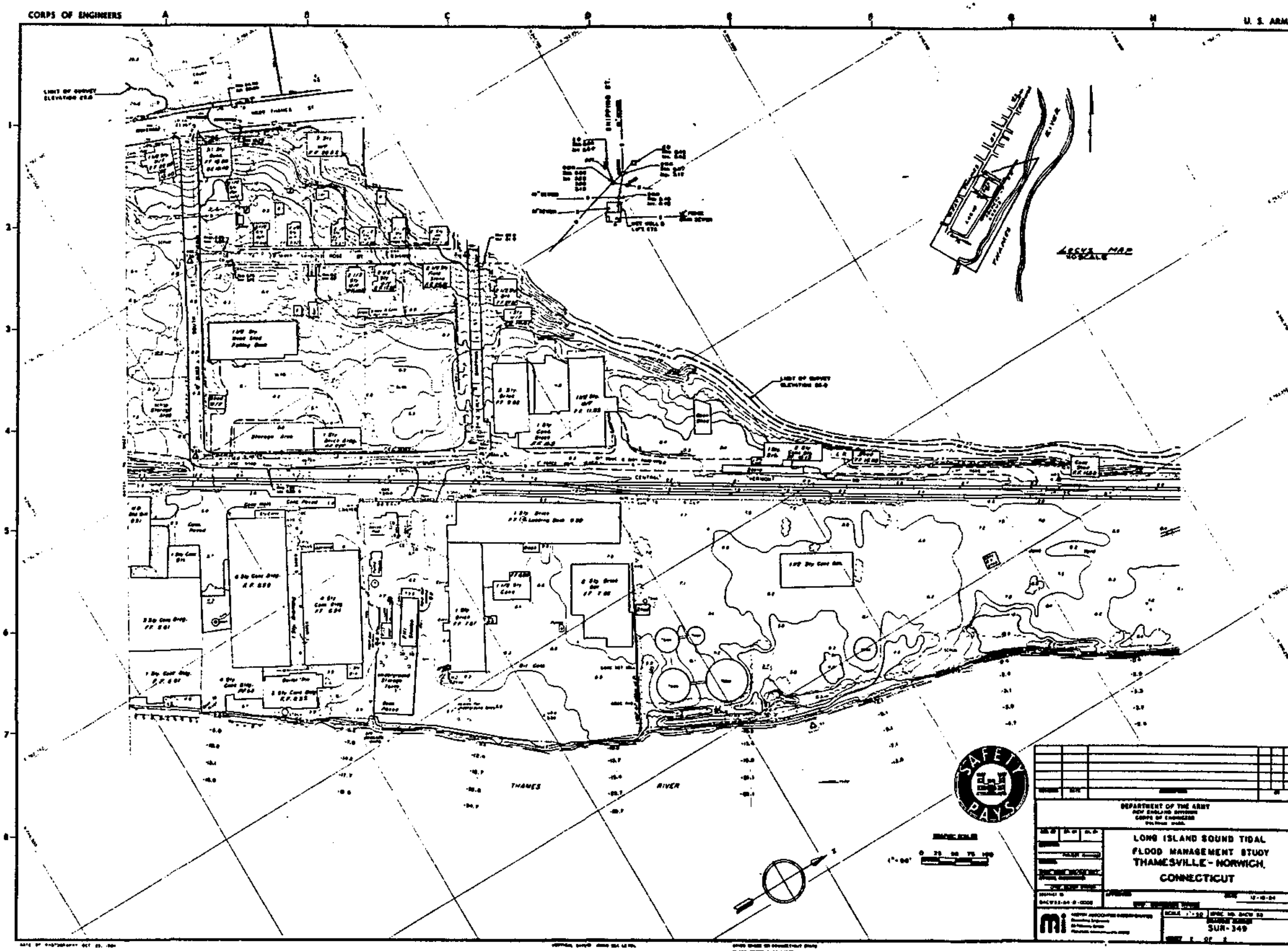

CORPS OF ENGINEERS
U. S. ARMY
A
B
C
D
E
F
G
H
THAMES
RIVER
SAFETY PAYS
DEPARTMENT OF THE ARMY
LONG ISLAND SOUND TIDAL
FLOOD MANAGEMENT STUDY
THAMESVILLE - NORWICH,
CONNECTICUT
SUR-349

Plate 1b

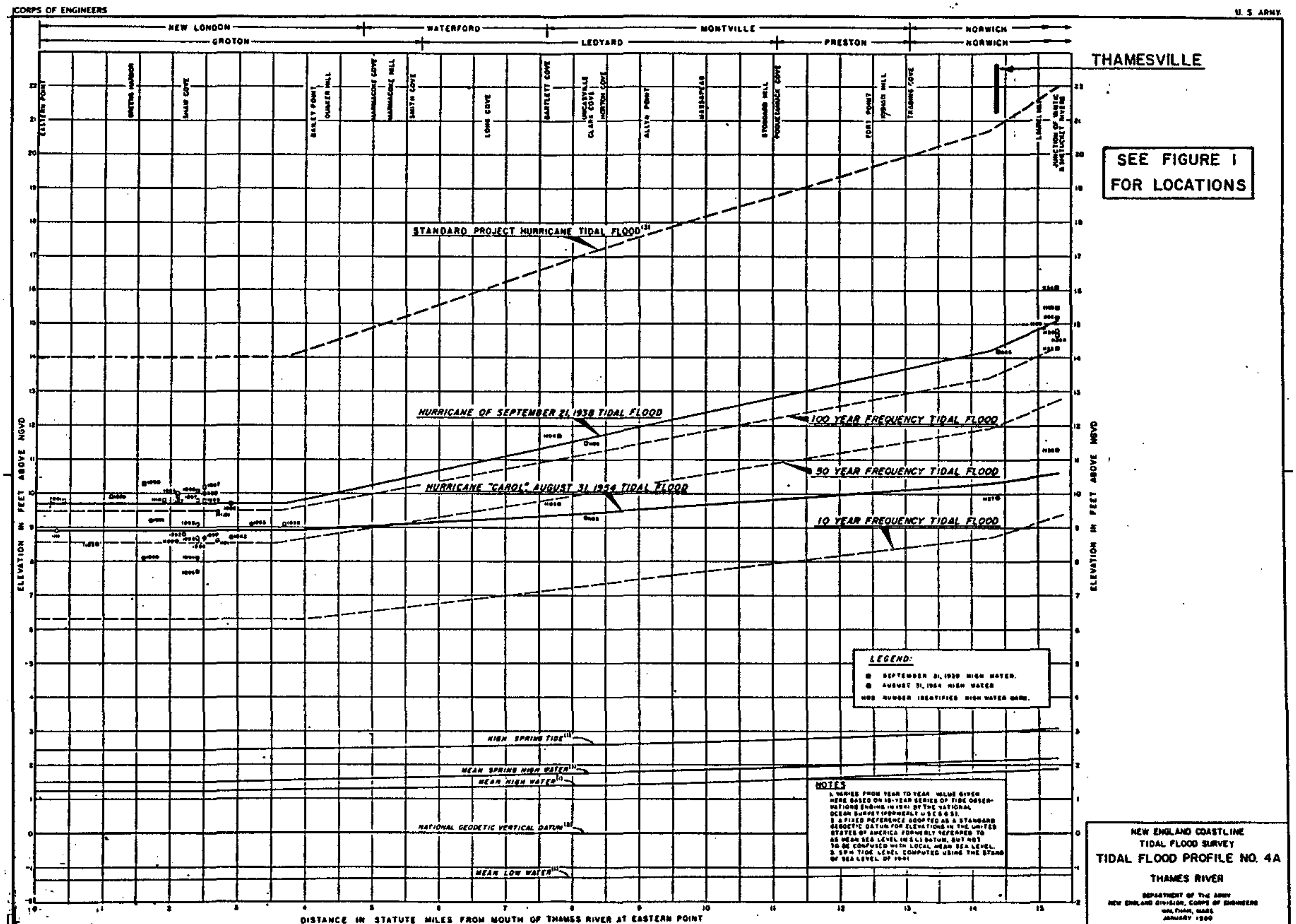

CORPS OF ENGINEERS
U. S. ARMY
NEW LONDON
WATERFORD
MONTVILLE
NORWICH
GROTON
LEDYARD
PRESTON
NORWICH
THAMESVILLE
SEE FIGURE I FOR LOCATIONS
STANDARD PROJECT HURRICANE TIDAL FLOOD(3)
HURRICANE OF SEPTEMBER 21, 1938 TIDAL FLOOD
100 YEAR FREQUENCY TIDAL FLOOD
50 YEAR FREQUENCY TIDAL FLOOD
HURRICANE "CAROL" AUGUST 31, 1954 TIDAL FLOOD
10 YEAR FREQUENCY TIDAL FLOOD
ELEVATION IN FEET ABOVE NGVD
LEGEND:
HIGH SPRING TIDE(1)
MEAN SPRING HIGH WATER(1)
MEAN HIGH WATER(1)
NATIONAL GEODETIC VERTICAL DATUM(2)
MEAN LOW WATER(1)
NOTES
DISTANCE IN STATUTE MILES FROM MOUTH OF THAMES RIVER AT EASTERN POINT
NEW ENGLAND COASTLINE
TIDAL FLOOD SURVEY
TIDAL FLOOD PROFILE NO. 4A
THAMES RIVER

PLATE 2

CORPS OF ENGINEERS

U. S. ARMY

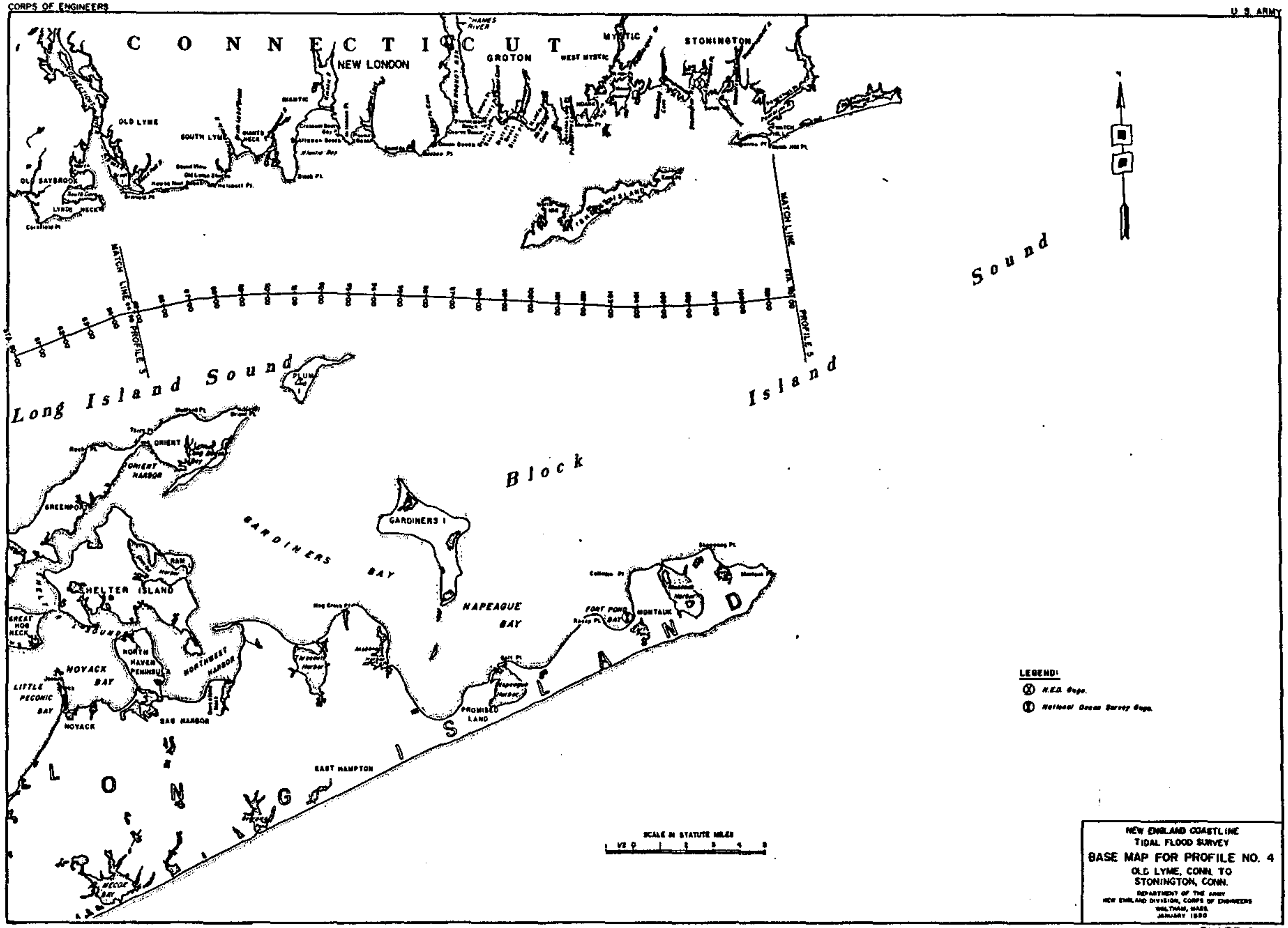
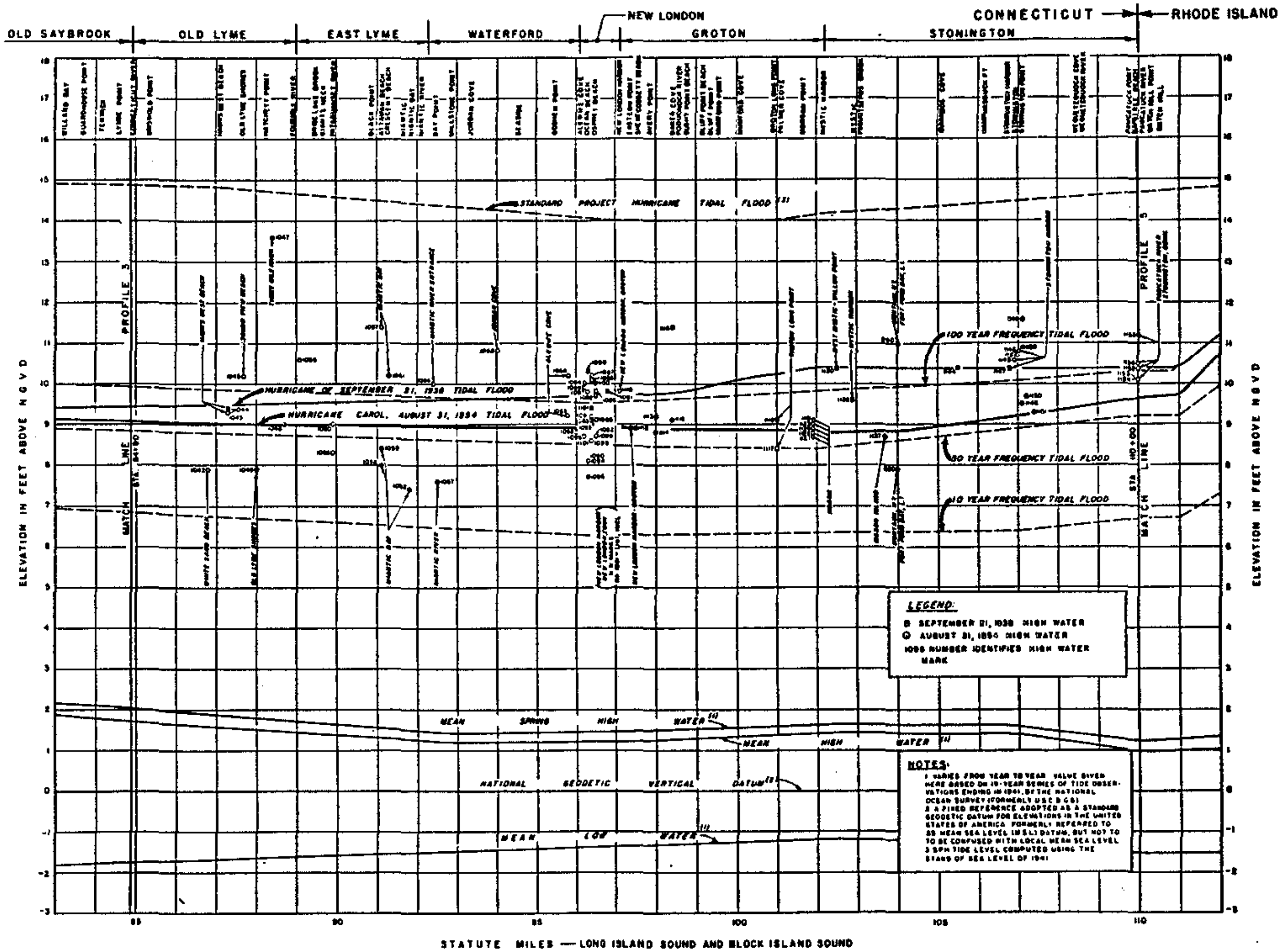


PLATE 3

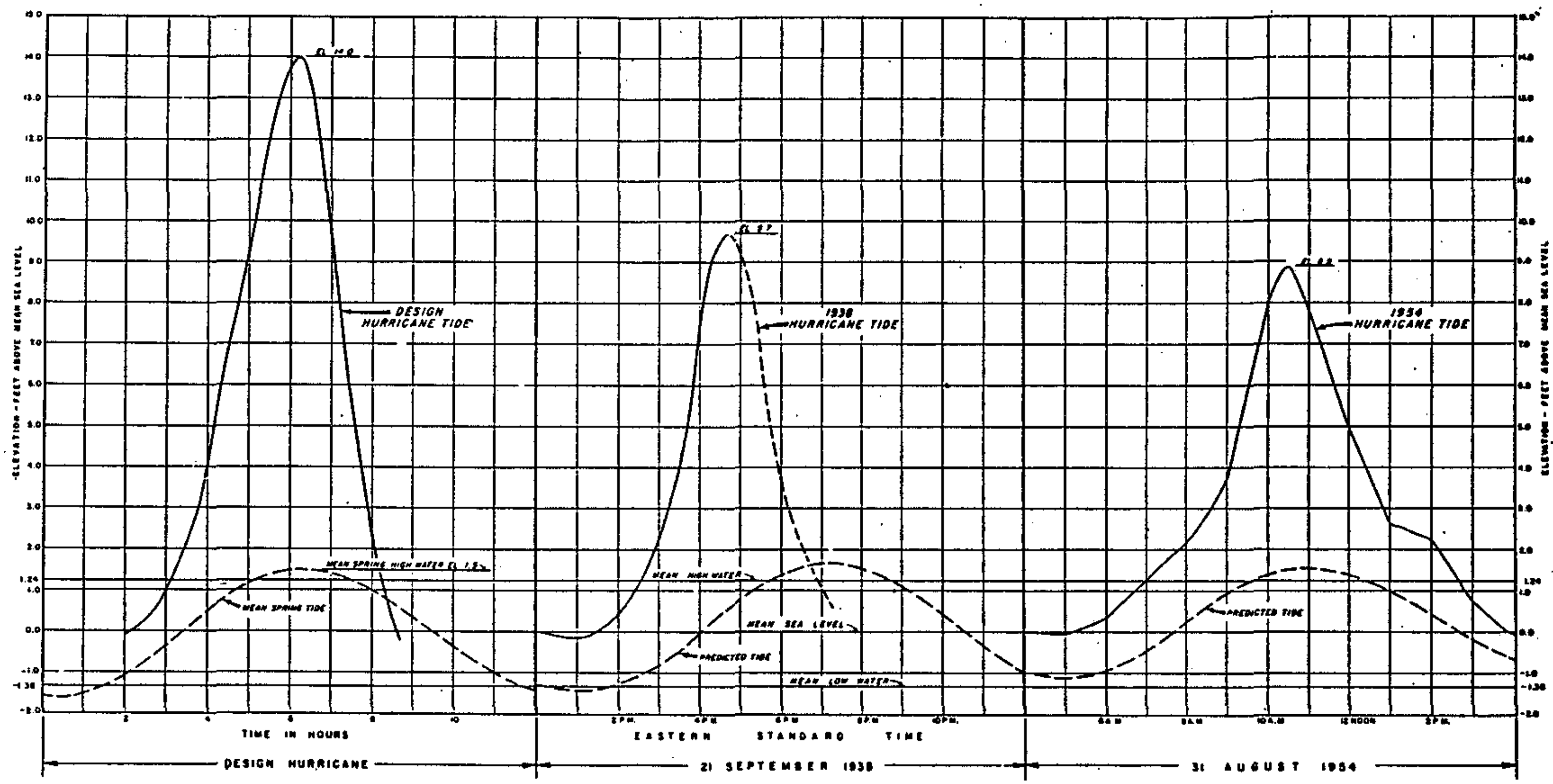


NEW ENGLAND COASTLINE
TIDAL FLOOD SURVEY

TIDAL FLOOD PROFILE NO. 4

OLD LYME, CONN, TO STONINGTON, CONN.

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS.
JANUARY 1960



NOTE:
Design hurricane tide curve based on Texas A&M surge calculations for a design storm with a track most critical to Long Island Sound and with the peak of the surge coincident with the peak of a mean spring tide

NOTE:
1938 - Hurricane tide curve based on U S C & G S. recording tide gage record and estimated tidal heights at New London

NOTE:
1954 - Hurricane tide curve based on U S C & G S recording tide gage record at New London

NEW LONDON HURRICANE BARRIER
NEW LONDON, CONNECTICUT
TIDE CURVES.
DESIGN HURRICANE, - 1938 & 1954

PLATE 5

APPENDIX 2

GEOTECHNICAL CONSIDERATIONS

THAMESVILLE, CONNECTICUT STAGE II STUDY

GEOTECHNICAL CONSIDERATIONS

1. Project Description. The purpose of the project is to reduce damages from flooding in the Thamesville Industrial area, Connecticut. Various wall and flood proofing schemes are being studied to find the most cost effective solution. Preliminary geotechnical studies were performed to further the continued planning of structural improvements.

2. Site Description. The proposed project site is an industrial area constructed on fill along the west bank of the Thames River in Thamesville, Connecticut. Concrete, metal, wood and brick structures up to six floors in height with bituminous concrete and gravel parking areas cover approximately the east three-fourths of the site. A railroad track and bituminous concrete road are situated on the west one fourth of the site and provide access to the structures and parking areas. The structures and railroad tracks are in very good condition (only a few cracks were observed in the slabs and structural walls of the structures). Several of the structures have been renovated for industry types which are lighter than for the type of industry that the structures were originally designed. Large cracks were noted in the bituminous concrete surfaces of the access road and parking areas.

3. Subsurface Explorations. Subsurface explorations were not specifically executed for this Stage II study. Two borings were performed for the design of a sewer interceptor which runs along the west edge of the site. American Drilling and Boring Company, Inc. performed the borings for the city of Norwich in August 1970. The depths of the borings were 10 and 15 feet. Standard penetration tests were typically executed at 5 foot intervals in the boreholes.

4. Subsurface Conditions. The nature of subsurface conditions at the project site was studied by reviewing available boring logs, geologic maps and a field visit by U. S. Army Corps of Engineers personnel. The general soil profile encountered is a granular fill underlain by alluvial material. The fill consists mainly of sand and has varying amounts of gravel, silt, organic silt, cinders, wood and rubble. The alluvial material is a mixture of sand, gravel, silt, and occasionally organic silt. Standard penetration tests performed in the boreholes indicated that the fill is loose to medium dense and the alluvial material is medium dense.

Groundwater was encountered in the boreholes at depths of 5.5 and 12.0 feet. It should be noted that the observed groundwater levels may fluctuate because of variation in rainfall, temperature, tides, stabilization time or other factors which differ from the conditions present at the time the observations were made.

5. Design and Construction Considerations.

a. Construction Materials. Concrete, gravel, sand and possibly stone would be required to construct flood walls. Concrete gravel, and sand are available from at least four suppliers within 15 miles distance from the proposed project. One possible supplier of stone is within 5 miles distance from the proposed project.

b. Flood Walls. Walls up to 10.4 feet high would be required to protect the area from a 100-year flood. In our opinion "I" walls with steel sheet pile cut-offs which extend to approximately a depth that is twice the height of the wall above the ground surface appear to be the most economic wall alternative at this time. The backfill zone on the landside of the proposed wall will be sloped and consist of pervious fill to accommodate surface water drainage. Stone protection may be required on the river side of the wall constructed along the east edge of the site.

c. Construction. Excavation of granular fill material for the proposed walls could be accomplished with a hydraulic excavator. *Localized dewatering may be required to construct the walls in the dry* during high tide periods (the maximum tide range is approximately 4 feet). Seasonal flooding of the Thames River does not appear significant enough to cause construction problems.

d. Utilities. It appears that many underground utilities exist at the proposed site. The location and size of the utilities are not known and may not be completely known at the time of construction. Adequate money should be included in the cost estimate to pay for relocation and possibly damage to the utilities

e. Future Explorations. Approximately one 30-foot drive sample boring per 200 lineal feet of wall will be required to design the walls. The borings will be used to better estimate the length of sheet piles required, amount and type of dewatering required, and the characteristics of the materials to be excavated. It is recommended that the explorations be executed during the next phase of the study.

APPENDIX 3

DESIGN & COST ESTIMATES

LONG ISLAND SOUND NON-STRUCTURAL STUDY

THAMESVILLE (NORWICH), CONNECTICUT

SUMMARY OF ANALYSIS AND DESIGN

A. PERTINENT DATA

1. Controlling Elevations

Due to the potential of wind-induced waves at the project site, standard freeboard allowances were increased by 1 foot. Top of floodwall elevations were determined by adding 3 feet of freeboard (2 feet plus an additional foot) to the predicted water surface elevation (WSEL). Levels of inundation (protection) for individual buildings were determined by adding 2 feet of freeboard (1 foot plus an additional foot) to the predicted WSEL to obtain the design WSEL.

2. Investigations

In order to identify flood-prone properties and to determine levels of flooding expected during the 20-year and 100-year events, a detailed topographic and hydrographic survey of the area was performed. The survey determined the type, size, structural composition and first floor elevation of each structure, and identified other major topographic features within the study area. Additional information was obtained from field notes and discussions with employees at area businesses.

B. ANALYSIS

The information gathered on each structure, along with the level of protection (depth of flooding) predicted for each structure during the 20-year (Design WSEL = 12.0 NGVD) and 100-year (Design WSEL = 15.4 NGVD) events is shown on Table 1.

Table 2 lists the non-structural measures considered to reduce damages along with the major advantages and disadvantages of each.

Based on the types of businesses and structures present, the levels of protection required and the high cost of relocating businesses outside the floodplain, the following measures were considered to be feasible:

- Removing high-value equipment and stock
- Making minor modifications to buildings and equipment subject to flooding
- Constructing floodwalls
- Flood Insurance
- Flood Forecast, warning and evacuation system

TABLE 1
PROPERTY DESCRIPTIONS AND REQUIRED PROTECTION LEVELS

Property		STRUCTURE Type	Found	First Floor EL	Floor Area (SF)	20-YR EVENT WSEL (NGVD)	Design WSEL (NGVD)	First Fl PROT'N (FT)	100-YR EVENT WSEL (NGVD)	Design WSEL (NGVD)	First Fl PROT'N (FT)
1. Lehigh Gas	A	1-Story Conc Blk	Slab on	10.0	30,000	10.0	12.0	2.0	13.4	15.4	5.4
	B	1-Story Corr Mtl	Grade	11.2	2,025	10.0	12.0	0.8	13.4	15.4	4.2
2. Sign Design		1-Story Corr Mtl	"	9.2	8,400	10.0	12.0	2.8	13.4	15.4	6.2
3. Conn Beverage Co.		1-Story Conc Blk/ Brick	"	11.0	25,000	10.0	12.0	1.0	13.4	15.4	4.4
4. Sachem Produce		3-Story Block/	"	8.9	7,800	10.0	12.0	3.1	13.4	15.4	6.5
		1-Story Block	"								
5. Doco Service, Inc.		2-Story Brick	"	7.3	15,750	10.0	12.0	4.7	13.4	15.4	8.1
6. Dahl Oil	A	1½-Story Brick	"	11.2	4,200	10.0	12.0	0.8	13.4	15.4	4.2
	B	1½-Story Conc Blk	"	10.2	700	10.0	12.0	1.8	13.4	15.4	5.2
7. Lehigh Oil		Conc Wall	--	9.4±	37,480	10.0	12.0	2.6	13.4	15.4	6.0
Tank Farm		Avg Ground	--	5.0±		10.0	12.0	7.0	13.4	15.4	10.4
8. Sawyer	A	6-Story Concrete	Slab on	6.6	19,800	10.0	12.0	5.4	13.4	15.4	8.8
Displays	B	1-Story Conc Blk	Grade	6.6	8,400	10.0	12.0	5.4	13.4	15.4	8.8
	C	3-Story Brick	"	6.5	4,000	10.0	12.0	5.5	13.4	15.4	8.9
9. Norwich Iron Office		1-Story Conc Blk	"	6.7±	1,200	10.0	12.0	5.3	13.4	15.4	8.7
and Metal Garage		6-Bay Conc Blk	"	6.7±	2,800	10.0	12.0	5.3	13.4	15.4	8.7
10. American Thermos		4-Story Concrete	"	8.0±	14,400	10.0	12.0	4.0	13.4	15.4	7.4
11. Nutmeg Wire, Inc.		1-Story Brick	"	6.7±	3,600	10.0	12.0	5.3	13.4	15.4	8.7
12. Abbott Seafood		1-Story Brick	"	7.0±	11,400	10.0	12.0	5.0	13.4	15.4	8.4
13. United Metal	A	3-Story Brick	"	9.9	5,000	10.0	12.0	2.1	13.4	15.4	5.5
of Conn.	B	1-Story Conc Blk	"	10.3	380	10.0	12.0	1.7	13.4	15.4	5.1
	C	1½-Story Wood Fr	"	11.0	9,500	10.0	12.0	1.0	13.4	15.4	4.4
14. Lehigh Oil	A	1-Story Brick	"	7.9/8.6	9,500	10.0	12.0	4.1/3.4	13.4	15.4	7.5
	B	1½-Story Conc Blk	"	7.0	2,000	10.0	12.0	5.0	13.4	15.4	8.4
	C	2-Story Brick	"	7.7	9,900	10.0	12.0	4.3	13.4	15.4	7.7

TABLE 2

NON-STRUCTURAL FLOOD DAMAGE REDUCTION MEASURES

	NON-STRUCTURAL MEASURE	STRUCTURE TYPE APPLICABLE	ADVANTAGES	DISADVANTAGES
1.	Acquisition/Demolition	All types	.Improved hydraulic performance .Complete protection .Improve declining areas .Relocation assistance available	.Excessive cost .Vacant land must be available for relocation .Advantages associated with being at flood-plain site are lost .Vacant site requires continued maintenance
2.	Physical Relocation	Practical limit on size and type which is economically feasible to move - usually limited to residential structures	Same as (1) above	Same as (1) above
3.	Relocation of Mechanical and Electrical Equipment	All types	.Physical damage reduced .Cost reduced by allowing selective protection of high-value contents	.Space must be available at new location .Residual damage to structure and contents not relocated .New patterns must be established for relocated property .Heating plants often must be replaced if elevated

	NON-STRUCTURAL MEASURE	STRUCTURE TYPE APPLICABLE	ADVANTAGES	DISADVANTAGES
4.	Rearranging Damageable Property within Existing Structure	All types	Same as (3) above	Same as (3) above
5.	Removing Damageable Stock and Equipment from Site	All types	Same as (3) above	.Dependent on receipt of flood warning or forecast .Residual damage to structure and contents not relocated
6.	Raising Superstructure	Practical limit on size and type which is economically feasible to raise - ideally wood frame residential and light commercial structures	.Physical damage reduced .Means of raising a structure are well known and contractors are readily available .Allows user/owner to continue operations at existing location .Flood insurance premiums are reduced	.Residual basement damage .Limit to height raised
7.	Temporary or Permanent Closures or Flood Shields (Floodproofing)	Generally large commercial and industrial structures with no basements	.Floodproofing may be done on a selective basis to only those openings thru which water enters and only to height desired .Easy and quick to implement	.Applicable only to brick or masonry type walls .Structures must be able to withstand the hydrostatic and uplift pressure of the design flood .Reduced likelihood of effective closure at night and during vacations with temporary closures

	NON-STRUCTURAL MEASURE	STRUCTURE TYPE APPLICABLE	ADVANTAGES	DISADVANTAGES
7.	Temporary or Permanent Closures or Flood Shields (Floodproofing) (Cont´d)			.May create a false sense of security and induce people to stay longer than they should
8.	Making Minor Modifications to Buildings and Equipment subject to Flooding	All types	.Physical damage reduced	.Prevents small percentage of damages
9.	Constructing Floodwalls	All types	.Not dependent upon the size, type or condition property being protected .Protects property outside a structure .Can be aesthetically pleasing and provide privacy and security	.Dependent on site conditions: Topography, property lines, available space, soil and groundwater conditions, velocity and depth of flooding .May require access openings & closures .Forces floodwater to other areas - increases floodplain area and depth of flooding
10.	Flood Insurance	All types	.Inexpensive to the insured at the subsidized rate .Indemnification is for any flood up to the limits of the policy	.Damages are not reduced .Indemnification is limited both in magnitude and type of damage

NON-STRUCTURAL MEASURE	STRUCTURE TYPE APPLICABLE	ADVANTAGES	DISADVANTAGES
10. Flood Insurance (Cont´d)			.A deductible provision for each loss makes it somewhat less attractive for low damage flooding
11. Flood Forecast, Warning and Evacuation System	All types	.Preparedness planning is almost always economically feasible and desirable. Something can usually be done even in areas where other flood loss reduction measures are implemented .A significant savings of lives may result in flash flood or water-related structural failure situations .Accurate forecasts and warnings may permit sufficient time to implement temporary protective measures	.The effectivenss of the warning system and response of the community cannot be accurately predetermined, consequently neither can potential flood-damage reduction .Requires a continuous awareness and information program, main tenance of equipment, etc. .Effectiveness of preparedness plans tend to diminish with increasing time between floods

In order to further identify the most feasible alternatives, the economic damage surveys for each property were reviewed to determine the type and elevation of the most significant damages.

Since most of the structures serve as warehouses for storage of various products, the majority of the total damages occur to stock/contents, followed by equipment/machinery, vehicles and the structure itself. It was also noted that a high percentage of the total damages occur to a cluster of properties in the northern corner of the study area.

C. DESCRIPTION OF PROPOSED IMPROVEMENTS

1. General

Since removing stock/contents and vehicles from the site and closing gate structures in floodwalls are non-permanent measures that require prior receipt of flood warning or forecast, it was assumed that current forecasting capabilities provide for the 8-12 hours of lead time required to put measures into effect. It was also assumed that the measures selected would be incorporated into formal plant closing procedures for each of the area businesses.

2. Plan A1 and Plan A2: Floodwalls with Individual Non-Structural Measures

For each alternative, a floodwall (Plan A1: 20-year, Plan A2: 100-year) would be constructed around selected, high-damage structures and individual flood damage reduction measures would be applied to the remaining structures that would be inundated.

As shown on Encl. 1, major features of the 20-year plan (Plan A1) include: 1,620 LF of reinforced concrete I-wall (Top El. 13.0 NGVD), 1 railroad gate, 1 street gate, 1-50 cfs pumping station, and individual non-structural plans offering varying degrees of protection for the remaining structures within the study area. The 100-year wall plan (Plan A2) would follow the same alignment and tie into high ground at El. 16.4 NGVD, adding an additional 120 feet of I-wall and a sandbag closure across the roadway at the western end of the wall. Damages to the remaining structures outside the wall resulting from the 100-year event would be reduced by the application of the same non-structural measures as the 20-year plan.

The floodwalls were designed for the 20-year (Design WSEL 13.0 NGVD) and the 100-year (Design WSEL 16.4 NGVD) events for two typical sections using the SHTWAL Program. The typical wall sections analyzed are shown on SH. 1 through 4 . Based on the subsurface conditions present, a reinforced concrete I-wall with a steel sheet pile cutoff extending to a depth approximately three times the height of the wall (above the ground surface) is required. Stone protection in front of the wall section parallel to the river will also be required.

Non-structural measures selected to reduce damages outside the floodwall include the following:

a. Modifying Buildings and Equipment

- Installing sewer check valves to prevent backflow.
- Installing fuel cutoffs in gas and oil lines
- Locating electrical service equipment and meters a maximum of 6 feet above first floor levels, and providing separate circuits for fixtures and outlets below this elevation
- Venting heating equipment and fuel storage tanks above the 100-year design WSEL
- Anchoring small, above-ground tanks to prevent flotation and constructing perimeter barriers to minimize damage from floating debris
- Keeping large fuel tanks filled above minimum levels to prevent flotation (no cost)

b. Removing high-value equipment and stock from the floodplain, and raising stock in multi-story buildings.

c. Flood insurance to cover the remaining damages determined to be unpreventable due to high cost and/or non-compatibility with business operations.

3. Plan B: Individual Non-Structural Measures for all Structures

Under this alternative, the individual flood damage reduction measures outlined in Plans A1 and A2 would be applied to all structures within the floodplain.

D. COST ESTIMATE

Estimated construction costs for the alternatives described are shown in the following tables:

Plan A1	20-year Floodwall with Individual Non-Structural Measures	Table 3
Plan A2	100-year Floodwall with Individual Non-Structural Measures	Table 4
Plan B	Individual Non-Structural Measures for all Structures	Table 5

Costs developed for the individual non-structural measures were based primarily on a lump-sum and square-foot basis. Costs for removing, storing and returning high-value stock and contents were based on rental rates for two trucks with drivers for three days. All costs are based on December 1985 price levels.

TABLE 3

COST ESTIMATE

PLAN A1

20-YEAR FLOODWALL W/INDIVIDUAL NON-STRUCTURAL MEASURES

A. Floodwall

Item	Quantity	Unit	Unit Price ($)	Cost ($)
Site Preparation	1	Job	L.S.	20,000
Mob. & Demob. Dredging Plant	1	Job	L.S.	40,000
Rem. Exist. Timber Piles	100	Ea.	100.	10,000
Demolish Wood Docks & Metal Shed	1	Job	L.S.	24,000
Control of Water	1	Job	L.S.	40,000
Excavation, Concrete	700	C.Y.	20.	14,000
Excavation, General	4,500	C.Y.	6.	27,000
Dredging	500	C.Y.	10.	5,000
Dumped Gravel Fill	900	C.Y.	12.	10,800
Comp. Gravel Fill	1,400	C.Y.	15.	21,000
Comp. Imp. Fill	900	C.Y.	10.	9,000
Stone Protection	1,600	C.Y.	35.	56,000
Gravel Bedding	500	C.Y.	20.	10,000
Concrete, I-Walls	1,500	C.Y.	300.	450,000
Steel Sheeting, I-Walls	38,000	S.F.	20.	760,000
Railroad Gate No. 1	1	Job	L.S.	100,000
Railroad Gate No. 2	1	Job	L.S.	150,000
Street Gate	1	Job	L.S.	75,000
Pumping Station (50 cfs)	1	Job	L.S.	520,000
Drainage	1	Job	L.S.	130,000
Utility Modifications	1	Job	L.S.	50,000
Wood Dock	750	S.F.	25.	18,750
Bit. Conc. Pavement	600	S.Y.	10.	6,000
	Subtotal:			$2,596,550
	Contingencies (±25%)			703,450
	TOTAL CONST. COST:			$3,300,000

TABLE 3

PLAN A1 (Continued)

B. Individual Non-Structural Measures

Summary

Property	Cost
Lehigh Gas	$ 70,000
Sign Design	26,000
Connecticut Beverage & Co., Inc.	40,000
Sachem Produce	28,000
Doco. Service, Inc.	54,000
Dahl Oil	20,000
Lehigh Oil Tank Farm	-
Norwich Iron & Metal	20,000
	$ 258,000
Contingencies (±25%)	62,000
Total Construction Cost:	$ 320,000
Floodwall: Total Construction Cost:	$3,300,000
Total Cost: Plan A1	$3,620,000

TABLE 4

COST ESTIMATE

PLAN A2

100-YEAR FLOODWALL W/INDIVIDUAL NON-STRUCTURAL MEASURES

A. Floodwall

Item	Quantity	Unit	Unit Price ($)	Cost ($)
Site Preparation	1	Job	L.S.	25,000
Mob. & Demob. Dredging Plant	1	Job	L.S.	40,000
Rem. Exist. Timber Piles	100	Ea.	100.	10,000
Demolish Wood Docks & Metal Shed	1	Job	L.S.	24,000
Control of Water	1	Job	L.S.	40,000
Excavation, Concrete	700	C.Y.	20.	14,000
Excavation, General	5,300	C.Y.	6.	31,800
Dredging	700	C.Y.	10.	7,000
Dumped Gravel Fill	1,200	C.Y.	12.	14,400
Comp. Gravel Fill	1,500	C.Y.	15.	22,500
Comp. Imp. Fill	1,100	C.Y.	10.	11,000
Stone Protection	1,500	C.Y.	35.	52,500
Gravel Bedding	500	C.Y.	20.	10,000
Concrete, I-Walls	3,000	C.Y.	300.	900,000
Steel Sheeting, I-Walls	60,000	S.F.	20.	1,200,000
Railroad Gate No. 1	1	Job	L.S.	150,000
Railroad Gate No. 2	1	Job	L.S.	230,000
Street Gate	1	Job	L.S.	120,000
Pumping Station (50 cfs)	1	Job	L.S.	520,000
Drainage	1	Job	L.S.	130,000
Utility Modifications	1	Job	L.S.	50,000
Sluice Gate	1	Job	L.S.	75,000
Wood Dock	750	S.F.	25.	18,750
Bit. Conc. Pavement	600	S.Y.	10.	6,000
Sandbag Closure	1	Job	L.S.	1,000
	Subtotal:			$3,702,950
	Contingencies (±25%)			897,050
	TOTAL CONST. COST:			$4,600,000

TABLE 4

PLAN A2 (Continued)

B. Individual Non-Structural Measures

Summary

Property		Cost
Lehigh Gas		$ 70,000
Sign Design		26,000
Connecticut Beverage & Co., Inc.		40,000
Sachem Produce		28,000
Doco. Service, Inc.		54,000
Dahl Oil		20,000
Lehigh Oil Tank Farm		-
Norwich Iron & Metal		20,000
		$ 258,000
	Contingencies (±25%)	62,000
	Total Construction Cost:	$ 320,000
Floodwall:	Total Construction Cost:	$4,600,000
Total Cost:	Plan A2	$4,920,000

TABLE 5

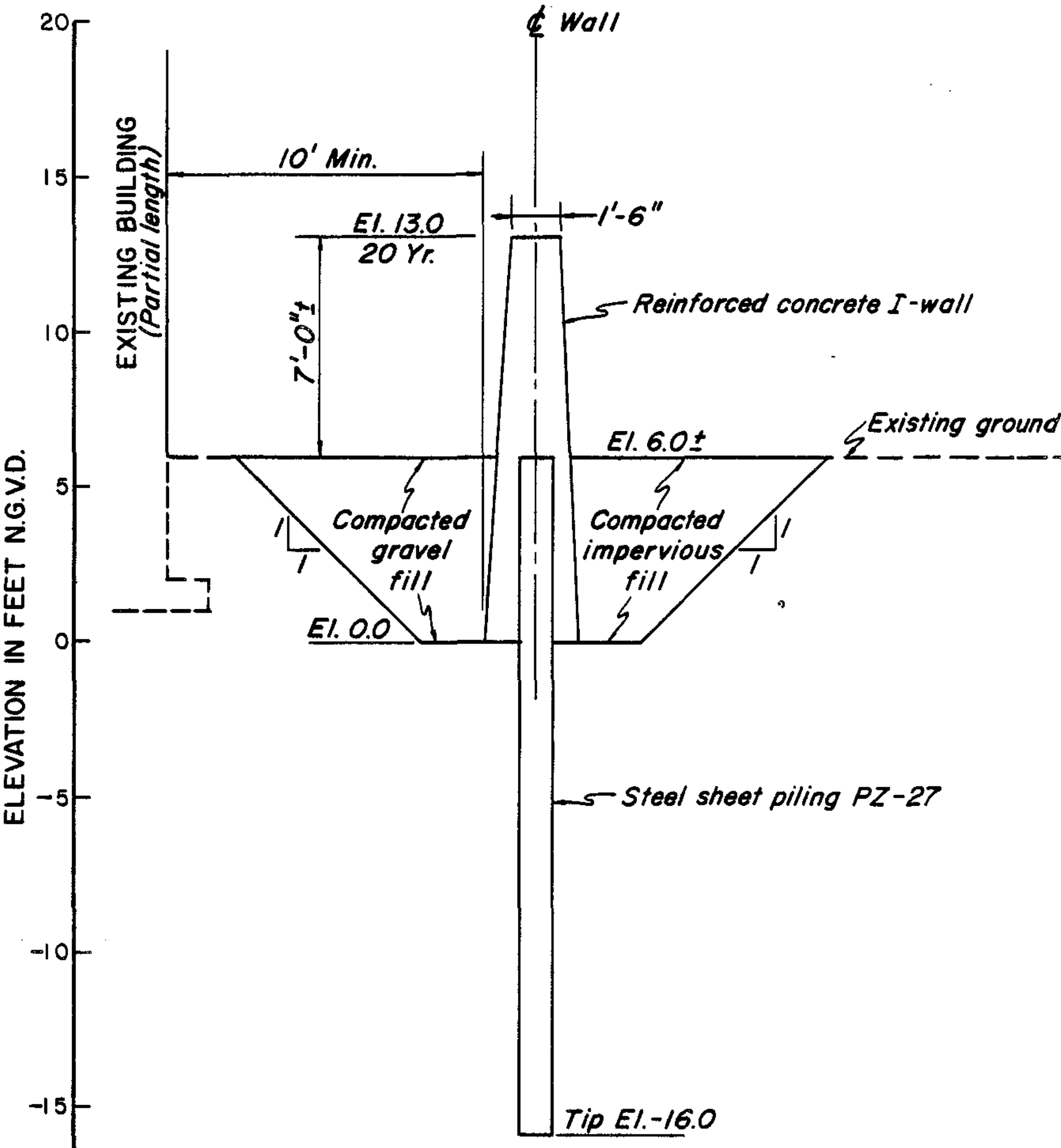
COST ESTIMATE

PLAN B

INDIVIDUAL NON-STRUCTURAL MEASURES FOR ALL STRUCTURES

Summary

Property	Cost
Lehigh Gas	$ 70,000
Sign Design	26,000
Connecticut Beverage & Co., Inc.	40,000
Sachem Produce	28,000
Doco. Service, Inc.	54,000
Dahl Oil	20,000
Lehigh Oil Tank Farm	-
Sawyer Displays	91,000
Norwich Iron & Metal	20,000
American Thermos	44,000
Nutmeg Wire, Inc.	20,000
Abbott Seafood	36,000
United Metal of Connecticut	62,000
Lehigh Oil	95,000
Subtotal:	$ 606,000
Contingencies (±25%)	154,000
Total Construction Cost:	$ 760,000

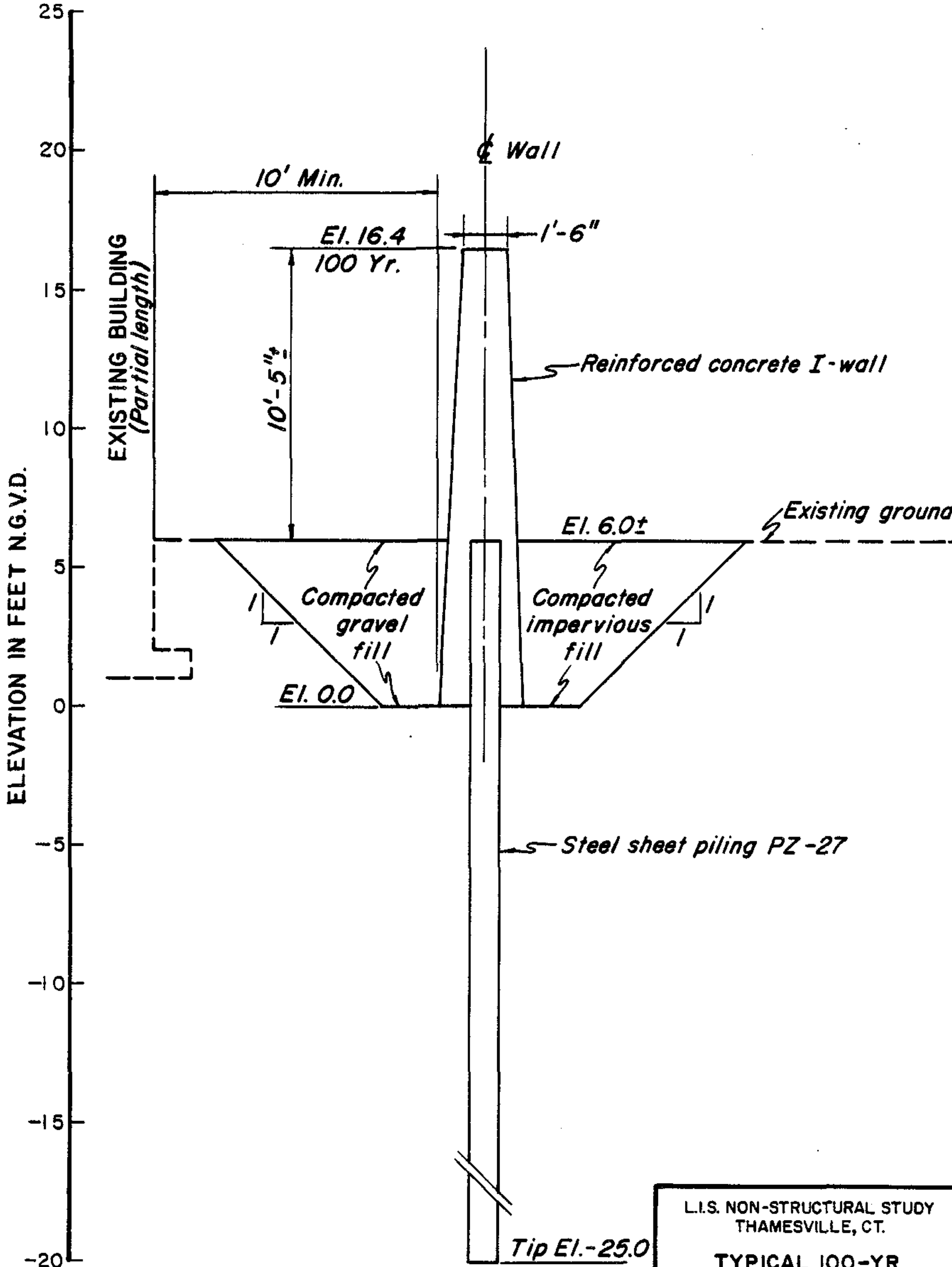


SECTION A-A

SCALE: 1" = 5'

L.I.S. NON-STRUCTURAL STUDY
THAMESVILLE, CT.

TYPICAL 20-YR.
WALL SECTION
PERPENDICULAR TO RIVER

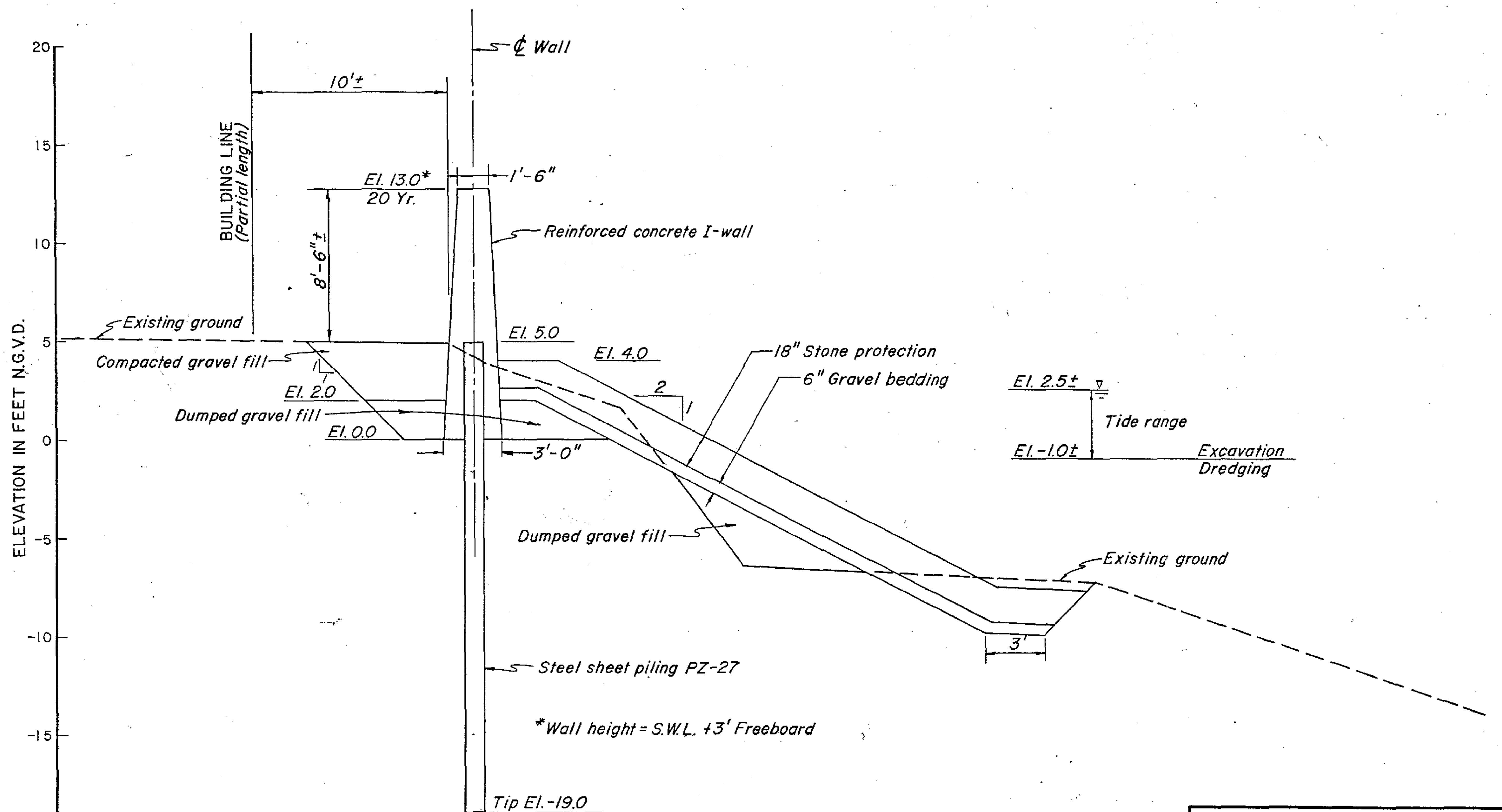


SECTION A-A

SCALE: 1" = 5'

L.I.S. NON-STRUCTURAL STUDY
THAMESVILLE, CT.

TYPICAL 100-YR.
WALL SECTION
PERPENDICULAR TO RIVER

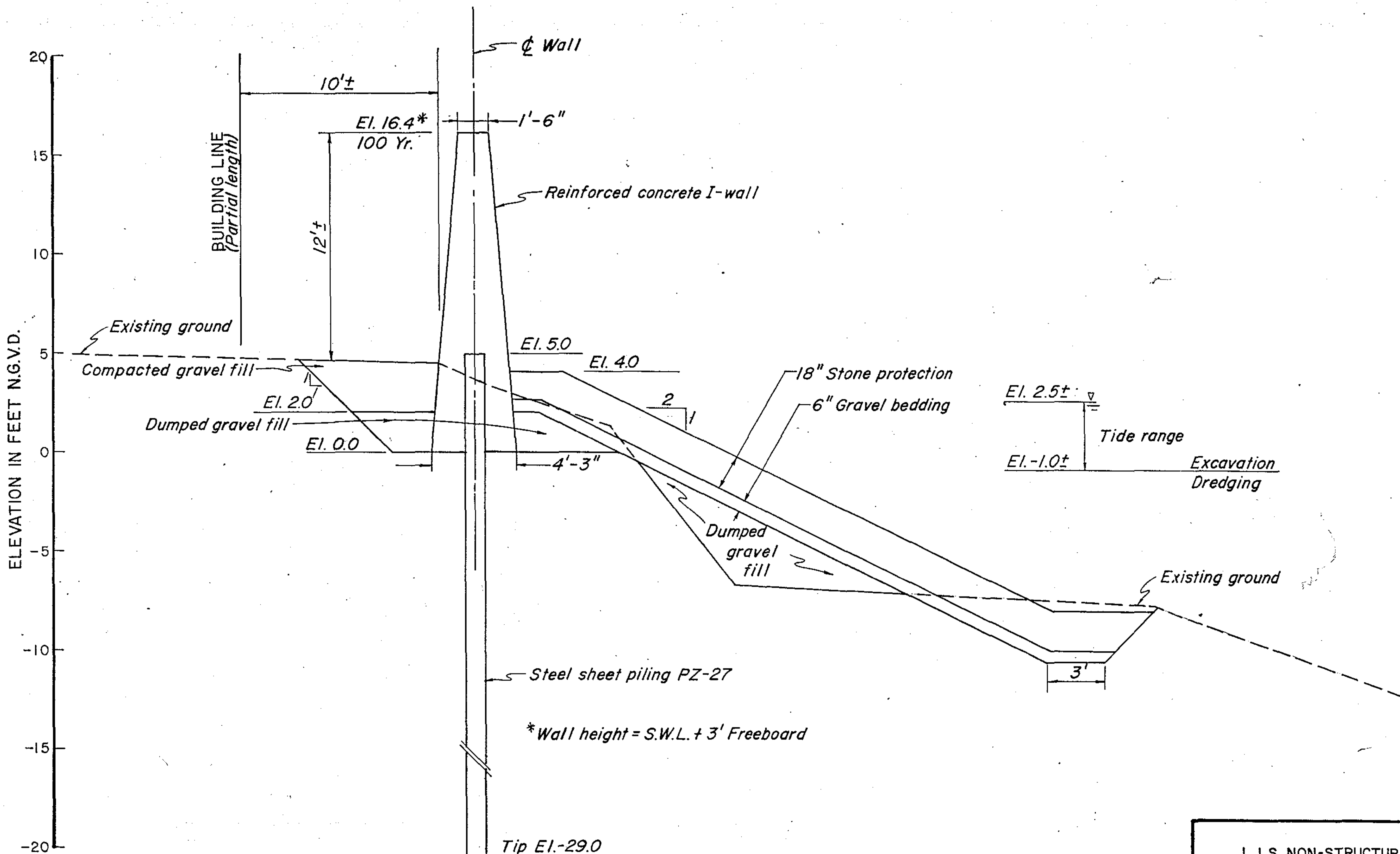


SECTION B-B

SCALE: 1" = 5'

L.I.S. NON-STRUCTURAL STUDY
THAMESVILLE, CT.

TYPICAL 20-YR. WALL SECTION
PARALLEL TO RIVER



SECTION B-B

SCALE: 1"=5'

L.I.S. NON-STRUCTURAL STUDY
THAMESVILLE, CT.

TYPICAL 100-YR. WALL SECTION
PARALLEL TO RIVER

APPENDIX 4

ECONOMIC ANALYSIS

LONG ISLAND SOUND, THAMESVILLE (NORWICH) CONNECTICUT
TIDAL FLOOD FLOOD MANAGEMENT STUDY
Appendix 4
Economic Analysis

February 1987

TABLE OF CONTENTS

PURPOSE

The appendix has been prepared for the purpose of examining alternative plans for providing tidal-flood protection to the Thamesville section of Norwich, Connecticut in terms of their economic feasibility and of the most economically efficient means of improving flooding conditions.

METHODOLOGY

The economic analysis in this report is based on the procedures accepted by the U.S. Army Corps of Engineers for evaluating the benefits and costs to national economic development (NED) which are associated with the plans for reducing flood losses. These procedures have been established in the following reference document.

> U.S. Army Corps of Engineers, Planning Guidance Notebook, regulation No. 1105-2-40 Planning - Economic Consideration, (July 9, 1983) including Appendix A prepared by the Water Resources Council entitled, Economic and Environmental Principles and Guidelines for Water and Related Land Sources Studies Implementation (March 10, 1983); Chapter II - National Economic Development (NED) Evaluation Procedures; Section IV - NED Benefits Evaluation Procedures; Section IV - NED Benefit Evaluation Procedures: Urban Flood Damage

The economic analysis is accomplished by first determining the economic justification of each of the proposed alternative plans in comparing the average annual national economic development (NED) benefits accuring to the plan compared to the average annual costs of the plan over its economic life (50 years). Benefits and costs are made comparable by conversion to an equivalent annual basis using an appropriate interest rate. During fiscal year 1986 (October 1, 1985 to 30 September 1986) a rate of 8-5/8 percent is employed in the formulation and evaluation of Federal water resource plans and projects. Costs are expressed in December 1985 prices. Flood losses, which are the basis of the estimation of benefits for the flood management plans are given early in the appendix at the October, 1984 price level, the date of the flood damage survey. The losses have, however, been adjusted to the 1985 level to make them consistent with the costs for the economic analysis. See tables 4 and 5. For the Federal Government to participate in a project, annual benefits should equal or exceed annual costs.

Secondly, net benefits (benefits minus costs) are calculated for each alternative plan in order to determine the plan that maximizes net benefits and therefore allocates Federal resources in the most efficient manner.

EXTENT AND CHARACTER OF THE STUDY AREA

The approximately 36 acre study area is located along the western shore of the Thames River in Thamesville in the southeastern part of the city of Norwich, Connecticut. The study area extends approximately one-half mile along the river and up to 800 feet to the west. It consists of a cluster of industrial and commercial establishments on a low narrow shelf along the west bank of the Thames River and a group of residential properties further west on higher ground towards West Thames Street. The Central Vermont Railway (Canadian Nation Railways) passes through the commercial/industrial properties in the study area.

The Thamesville study area consists of approximately 30 properties: 14 commercial, 6 industrial and 10 residential.

FLOOD LOSSES

Damage Survey

Damage evaluators from the New England Division of the Corps of Engineer conducted damage surveys of the properties in the study area in 1980 and October 1984. The interviewed the property owners and managers of properties and city officials concerning damages to be expected from a recurrence of a flood similar to the hurricane flood of 1938. Dollar values estimates were made for physical damages to site, structures, contents, vehicles, and utilities. In addition, estimates were prepared in one-foot increments up to 3 feet above and 9 feet below the elevation (14.5 feet NGVD) of the September, 1983 flood.

The 1984 survey resulted in an estimated 12,879 million dollars in damages for a flood similar to that of 1938. These damages were subsequently updated to reflect recent land use and damage preventive measures which flood plain occupants undertake during times of flood emergencies. For example, some occupants systematically move certain properties above or out of flooded areas during impending storms. These activities reduce potential vehicle, equipment and stock damages up to 50 percent. The revised estimates indicate that a recurrence of the 1938 flood would cause damages of approximately $9 million. Table 1 presents the distribution of these losses in the four land use categories.

Table 1
Long Island Sound - Tidal Flood Management Study
Thamesville, Norwich, CT
Estimated Flood Damages for a Flood Event Similar to
That of 1938

	Damages ($1000 1984)	Percent of Total Damages
Commercial	$7329	81.4
Industrial	1452	16.1
Residential	32	0.4
Public and Institutional	195	2.1
Totals	9008	100.0

A single property, both owner and leasor occupied, accounts for approximately 54 percent of the commercial losses.

Recurring Losses

Recurring losses are those potential damages which are expected to occur under projected development at various flood stages. Evidence of the susceptability of the study area to flood damages is demonstrated by intergrating information which relates damages to stage from the field survey with hydrologic stage-frequency data in order to produce relationships between damages and their frequency of occurrence. Table 2 presents these relationships for the study area.

Table 2
Long Island Sound - Tidal Flood Management Study
Thamesville, Norwich CT
Relationship of Probable Flood Events to Expected
Flood Losses

Recurrence Interval of Flood Events (Years)	Flood Damages ($1000 1984)
500	10,003
200	9,185
100	8,541
50	7,356
20	4,692
10	2,522
5	890

Annual Losses

Average annual losses were estimated using the standard damage frequency techniques described above, that is, stage-damage information obtained by the field survey was combined with hydrologic stage-frequency data to produce damage-frequency corrections. The probability of reaching each specific flood stage during a yearly period was multiplied by the corresponding dollar value of damage. The summation of these expected values result in potential annual losses. Estimated average annual damage due to flooding in the study area are estimated at $814,500. This figure reflects damage preventive measures which flood plan occupants undertake during flood emergencies.

ALTERNATIVE FLOOD MANAGEMENT PLANS AND COSTS

The alternative flood management plans are described in detail the main report. First costs of implementing the four alternative improvement plans vary from $51,000 to $8,378,000. The first costs include contingencies, engineering and design, and supervision and administration. Table 3 presents the calculations for total annual costs for each alternative including interest during construction and operation and maintenance costs.

Alternative 1 - Floodwarning and Emergency Evacuation

Alternative 1, consisting of the use of an existing flood warning system (8 to 12 hours notice) and emergency evacuation or procedures to temporarily remove flood prone properties from the floodplain, would require minimal investment for tidal monitoring equipment, and containers and pallets for stock, for example, and modest recurring costs for the updating of plans, training and the actual evacuation of people and property. These costs are estimated to be approximately $23,000 on an annual basis.

Depending on the property, the measures included in Alternative 1 are designed to reduce damages in the following categories and over the indicated ranges,

Stock	- 0 to 65%
Furnishings and records	- 0 to 50%
Cleanup	- 0 to 25%
Vehicles	- 100%

Alternative 2 - Cluster Floodwall and Non-Structural Measures

Alternatives 2A and 2B consist of structural and non-structural elements. Variants A and B refer respectively to 20 year (elevation 13.0 feet NGVD) and 100 year (elevation 16.4 feet NGVD) levels of protection for the structural elements including freeboard. These structural elements are similar to those Alternatives 3 except they protect only 4 commercial and 5 industrial properties and all of the residential properties. Those properties outside of the floodwalls would be floodproofed in the same manner as Alternative 3.

Alternative 3 - Full Floodwall

Alternative 3 consists of a system of reinforced concrete walls with steel sheet piling, two railroad gate structures, one pumping station and other appurtenance works to protect all properties in the study area except Norwich Iron and Metal. Alternative 3 has two variants: A and B. These offer protection including 3 feet of freeboard from 20 year (elevation 13.0 feet NGVD) and 100 year (elevation 16.4 feet NGVD) recurrence floods. The first costs for variants A and B respectively are $6,394,000 and $8,378,000.

Alternative 4 - Floodproofing

Floodproofing consists of measures to permanently protect (remove, raise, etc.) equipment, stock, furnishing, records, and other contents and services (electrical, etc). It would not be practicable to floodproof all properties to the same level of protection. The level of protection therefore varies from one property to another. First cost for Alternative 4 is $917,000.

Table 3
Long Island Sound - Tidal Flood Management Study
Thamesville, Norwich, CT
Costs of Alternative Flood Protection Plans
($1000 1985)

Alternative 1 - Floodwarning and Emergency Evacuation

(1) First Cost (Inc. Contingencies etc.)	$51
(2) Interest during construction	-
(3) Investment	51
(4) Interest plus amortization (50 yrs at 8 5/8%)	5
(5) Annual Operations and Maintenance	18
(6) Total Annual Cost	23

	Level of Protection for Structural Elements	
	20 Year Recurrence Flood	100 Year Recurrence Flood
Alternative 2 - Cluster Floodwall and Non-Structural Measures	A	B
(1) First Cost (Inc. Contingencies; E&D, 7%; S&A 10.5%)	$4,291	$5,817
(2) Interest during construction (2 yrs)	365	494
(3) Investment cost	$4,656	6,311
(4) Interest plus amortization (50 yrs at 8 5/8%)	408	553
(5) Annual Operations and Maintenance	3	4
(6) Total Annual Cost	411	557
Alternative 3 - Full Floodwall Measures	A	B
(1) First Cost (Inc. Contingencies; E&D 4%; S&A 6%)	$6,394	$8,378
(2) Interest during construction (3 yrs)	853	1,117
(3) Investment cost	7,247	$9,495
(4) Interest plus amortization (50 yrs at 8 5/8%)	635	832
(5) Annual Operations and Maintenance	12	12
(6) Total Annual Cost	647	844
Alternative 4 - Floodproofing		
(1) First Cost (Inc. Contingencies etc.)	$ 917	
(2) Interest during construction (1 year)	37	
(3) Investment cost	$ 954	
(4) Interest plus amortization (50 yrs at 8 5/8%)	84	
(5) Annual Operations and Maintenance	20	
(6) Total Annual Cost	104	

Note: E&D is Engineering and Design and S&A is Supervision and Administration

BENEFIT ANALYSIS

The benefit analysis aims to measure the net beneficial contributions to National Economic Development (NED) associated with each of the alternative plans for flood protection of the study area in Norwich (Thamesville). The three theoretical benefit categories area: (1) inundation reduction; (2) intensification; and (3) location, which were analyzed with respect to the improvement plans under consideration and the character of the study area. Only benefits in the inundation reduction category have been taken.

Inundation reduction benefits theoretically may take three forms: (1) reduction in flood damages; (2) reduction in emergency costs; (3) reduction in the National Flood Insurance Program overhead.

Emergency costs and National flood Insurance Program overhead are not significant and would be applied nearly equally to all improvement plans. Since their consideration is neither necessary for the establishment of the economic feasibility of each plan nor for the selection of the most economically efficient plans, they are not part of the analysis.

At present the occupants of the study area undertake certain measures such as the removal of up to 50 percent of vehicles, equipment and stock from the floodplain in anticipation of floods. The damages incurred by the occupants after they have undertaken these measures defines the without plan condition with damages of approximately $814,500 annually. With respect to the with plan condition each of the four alternatives is expected to reduce but not eliminate flood damages entirely in the study area. Annual residual damages for the four plans vary from $45,000 to $802,000 in 1985 prices. Plans and structural elements have the higher rates of damage reduction.[1] The average annual benefits for each improvement plan are simply the differences between average annual losses without the execution of any plan and the residual damages associated with each plan. Table 4 presents the average annual damages for the without and with plan conditions for each of the alternatives and the resulting benefits.

ECONOMIC EVALUATION

The results of the economic analysis are presented in Table 5. Alternatives 1 and 2 are economically feasible since their benefit - cost ratios are one or greater. Alternative 1, Floodwarning and Emergency Evacuation, maximizes net benefits and is therefore the most economically efficient plan.

1/ Concerning the structural alternatives and structural elements of composite structural and non-structural alternatives, flood damage reductions for the lower half of the freeboard range have been used in the benefit calculations.

Table 4
Long Island Sound - Tidal Flood Management Study
Thamesville, Norwich, CT
Annual Benefits for Alternative Flood Protection Plans
($1000 1984 and 1985 Dollars)

	Average Annual Damages Without Plans		Average Annual Damages With Plans		Average Annual Benefits	
	1984	1985	1984	1985	1984	1985
	815	833				
1. Floodwarning and Emergency Evacuation			627	641	188	192
2. Cluster Floodwall and Non-Structural Measures						
A. Protection to 20 year recurrence flood			281	287	534	546
B. Protection to 100 year recurrence flood			169	173	646	660
3. Full Floodwall						
A. Protection to 20 year recurrence flood			204	208	611	625
B. Protection to 100 year recurrence flood			44	45	711	788
4. Floodproofing			785	802	30	31

Note: Price Adjustment 1984 to 1985 is +2.2 percent

Table 5
Long Island Sound - Tidal Flood Management Study
Thamesville, Norwich, CT
Economic Evaluation of Alternatives
(1000 1985 Dollars)

Annual Alternatives	Annual Benefits ($1000)	Benefit- Costs ($1000)	Net Cost Ratios	Benefit ($1000)
1	192	23	8.4	169
2A	546	411	1.3	135
2B	660	557	1.2	103
3A	625	647	0.97	negative
3B	788	844	0.93	negative
4	31	104	0.30	negative

APPENDIX 5

ENVIRONMENTAL RECONNAISSANCE STUDY

LONG ISLAND SOUND - THAMESVILLE, CONNECTICUT

TIDAL - FLOOD MANAGEMENT

ENVIRONMENTAL RECONNAISSANCE STUDY

OCTOBER, 1985

Prepared for:

DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION
CORPS OF ENGINEERS
424 TRAPELO ROAD
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CONTRACT NO. DACW 33-85-D-0001

DELIVERY ORDER NO. 0010

Prepared by:

HMM ASSOCIATES, INC.
336 Baker Avenue
Concord, Massachusetts 01742

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EXECUTIVE SUMMARY

This report presents the results of an Environmental Reconnaissance Study of the Long Island Sound - Thamesville, Connecticut Tidal Flood Management area. This study provides an inventory of existing environmental conditions and an assessment of the consequences associated with flood protection alternatives. No field surveys or sampling were conducted; however, a site visit was made. All data and assessments were based on the site visit and on information available in the literature, by personal communication or provided by the Corps.

The study area, within the City of Norwich, Connecticut has historically experienced tidal flooding during major storm events. The Corps of Engineers, New England Division estimates that the average annual damages in the study area exceed $1,000,000 (Waskiewicz, 1985). To reduce potential flood damages three alternative actions have been considered.

Each of the proposed alternatives would include a flood warning system and development of flood emergency procedures.

Alternative No. 1 would provide flood damage protection for a segment of the project area through floodproofing of buildings and/or rearrangement of the buildings' contents. This alternative could be implemented with minimal impacts on the environment. Its major drawback is that it could necessitate the removal or transfer of goods and equipment and/or installation of floodshields in the event of a major storm.

Alternative No. 2 involves the construction of an earthen dike and concrete floodwall, a pumping station and other appurtenant structures which would effectively protect the entire project area. However, this alternative would have possibly significant negative impacts on the environment. The implementation of Alternative No. 2 would affect not only the Thamesville area but also the surrounding communities. The removal, transport and disposal of 100,000 cubic yards of spoil as well as the acquisition, transport and placement of an additional 200,000 cubic yards of material to construct flood control facilities would have possibly significant negative impacts on area terrestrial and aquatic ecosystems.

Alternative No. 3 involves the construction of a concrete floodwall which would provide flood control for a portion of the project area. Construction-related impacts would have some adverse affects on the environment; however, in the long-term, impacts would be primarily beneficial.

1.0 INTRODUCTION

1.1 Overview of Thamesville Study

This Environmental Reconnaissance Study was conducted along the Thames River in the community of Thamesville, Connecticut as part of the overall Long Island Sound Flood Management Program. The area of concern includes a 36 acre band of residential, commercial and industrial properties located along the floodplain of the Thames River (see Figures 1.1-1 and 1.1-2). The objectives of the study were to:

1. Provide an inventory of the existing environmental conditions, and

2. Assess the impacts associated with the implementation of flood protection alternatives.

To achieve these objectives a survey was conducted to acquire existing information on the project area with respect to the physical, biological and social environments. In addition, these data were supplemented with a field survey and communications with pertinent federal, state and local governmental agencies and organizations.

1.2 Areawide Environmental Issues

Areawide environmental issues are closely correlated to the Thames River. Key issues for the physical, biological and socioeconomic environments are as follows:

Physical Environment	o Climate - severe storm frequency (i.e., nontropical and tropical storms)
	o Hydrodynamics - tides, currents and water depths
	o Erosion - sedimentation and changes in topography
	o Water Quality - chemical and physical properties
Biological Environment	o Aquatic Ecosystem - fisheries and shellfish
Socioeconomic Environment	o Flood Damage - impacts and costs associated with tidal flooding

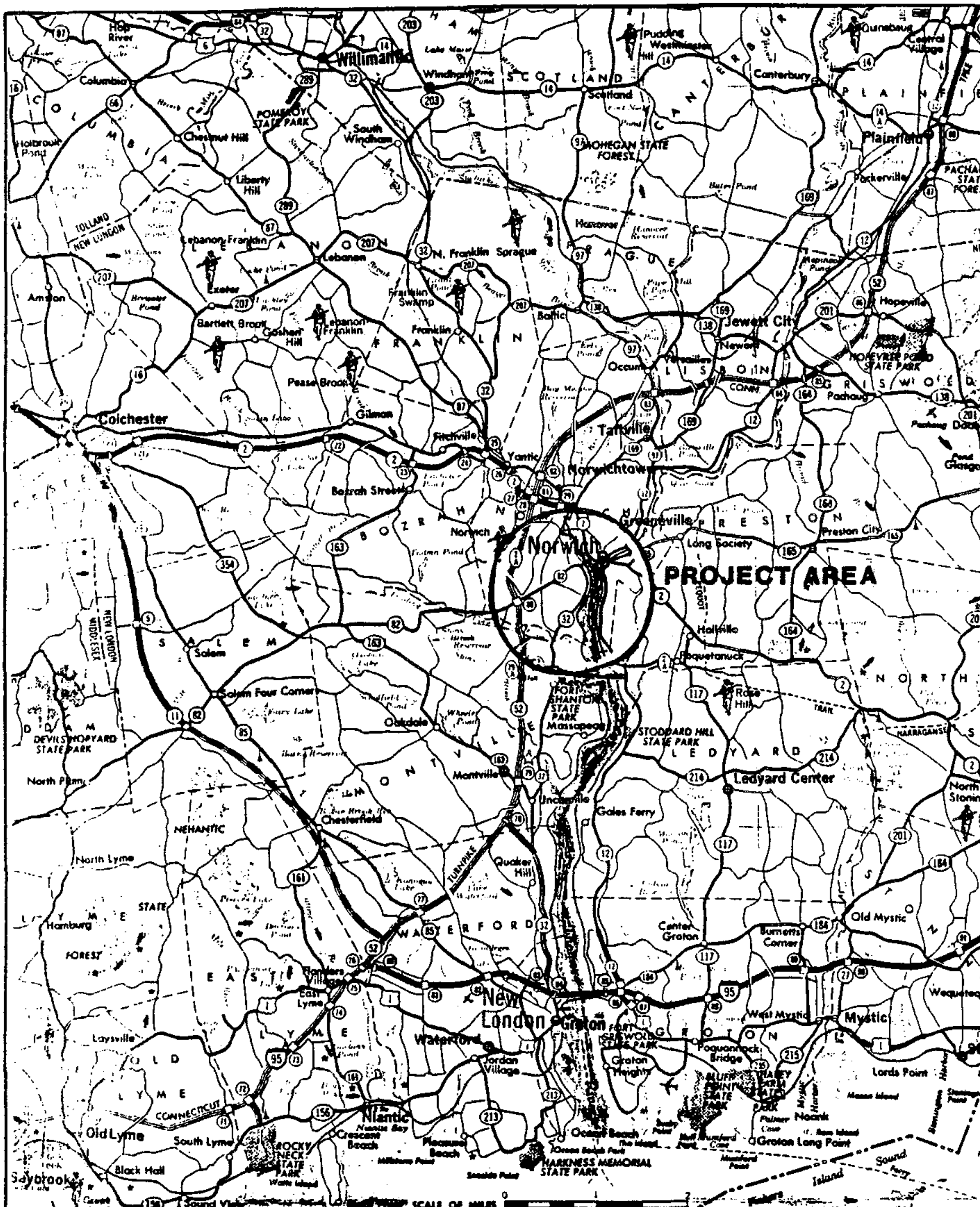

FIGURE 1.1-1 General Project Area
(Connecticut Department of
Environmental Protection, 1980)

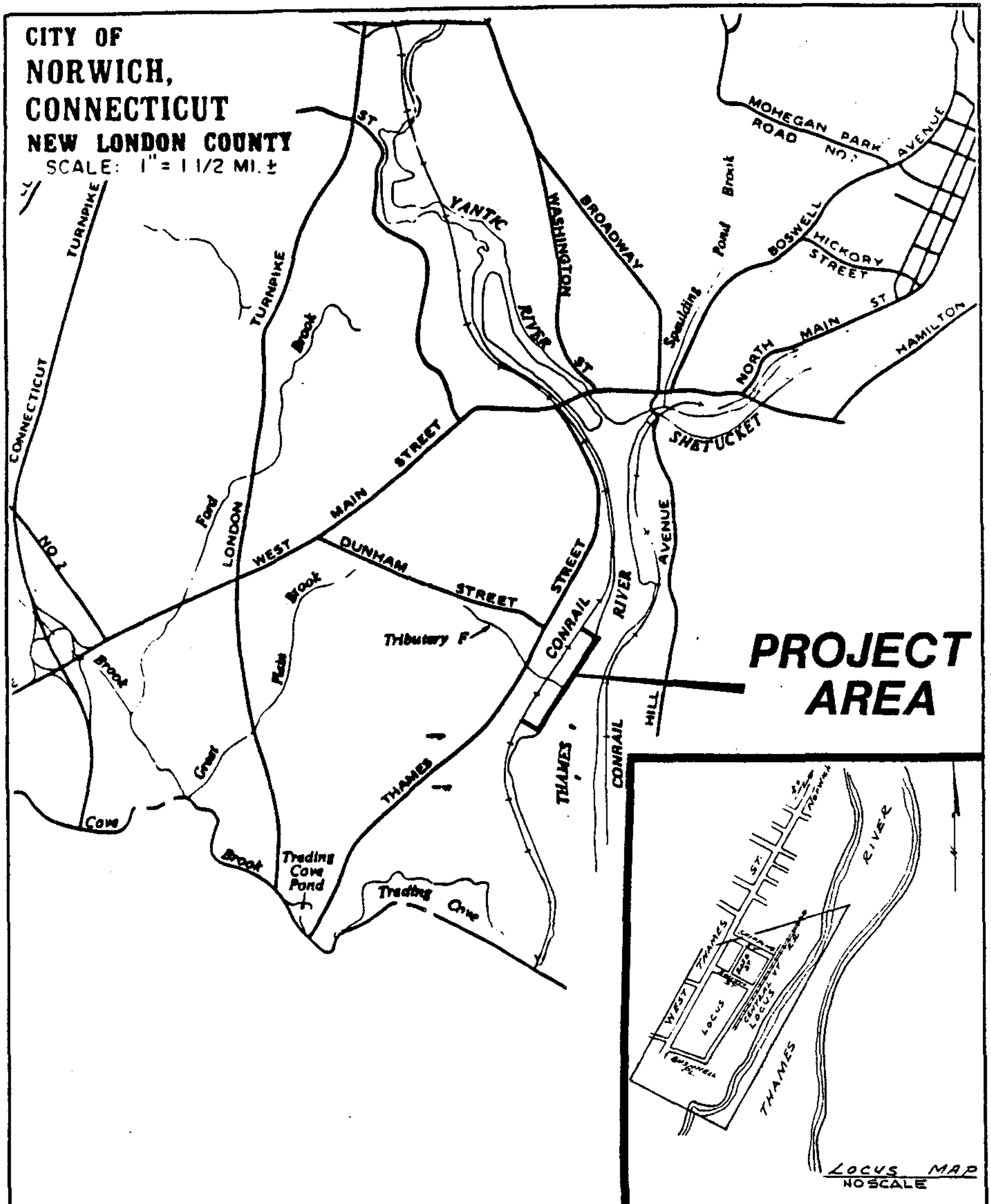

FIGURE 1.1-2 Thamesville Project Area
(U.S. Army Corps of Engineers,
New England Division, 1981 and
Mistry Associates, Inc., 1984)

- o Navigation - channel width, depth and hazards
- o Recreation - open space, boating and fishing

1.3 Alternative Actions

A number of alternative actions have been proposed to provide tidal flood management for the project area. Each of the proposed alternatives includes a flood warning system and an emergency procedures plan.

Alternative No. 1 would provide flood damage reduction by floodproofing a segment of the project area. This alternative includes various types of flood protection from rearranging contents of buildings and allowing flooding to waterproofing walls and providing shielding for openings or constructing ring walls.

Alternative No. 2 involves the construction of an earthen dike and concrete floodwall, a pumping station, and other apurtenant structures to protect the entire project area. This alternative would provide protection for all of the commercial and industrial facilities and residences within the confines of the dike and floodwall system (see Figure 1.3-1).

Alternative No. 3 would provide flood protection for a portion of the project area. It involves the construction of a concrete floodwall to reduce flood damages (see Figure 1.3-2).

An overview of potential actions which may be employed under these alternatives is presented in Table 1.3-1.

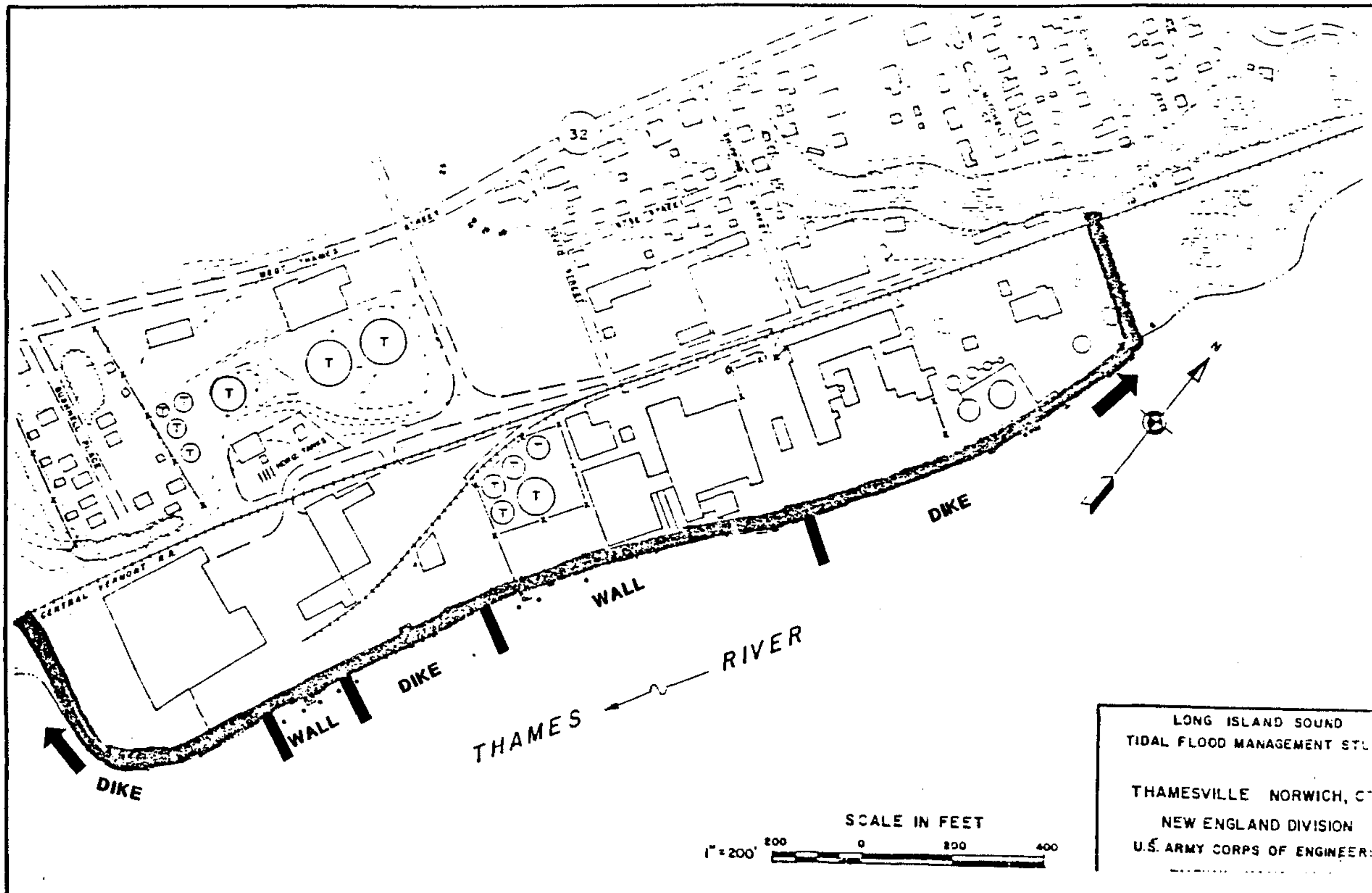

Figure 1.3-1 Alternative No. 2 - Dike and Floodwall Construction (Waskiewicz, 1985)

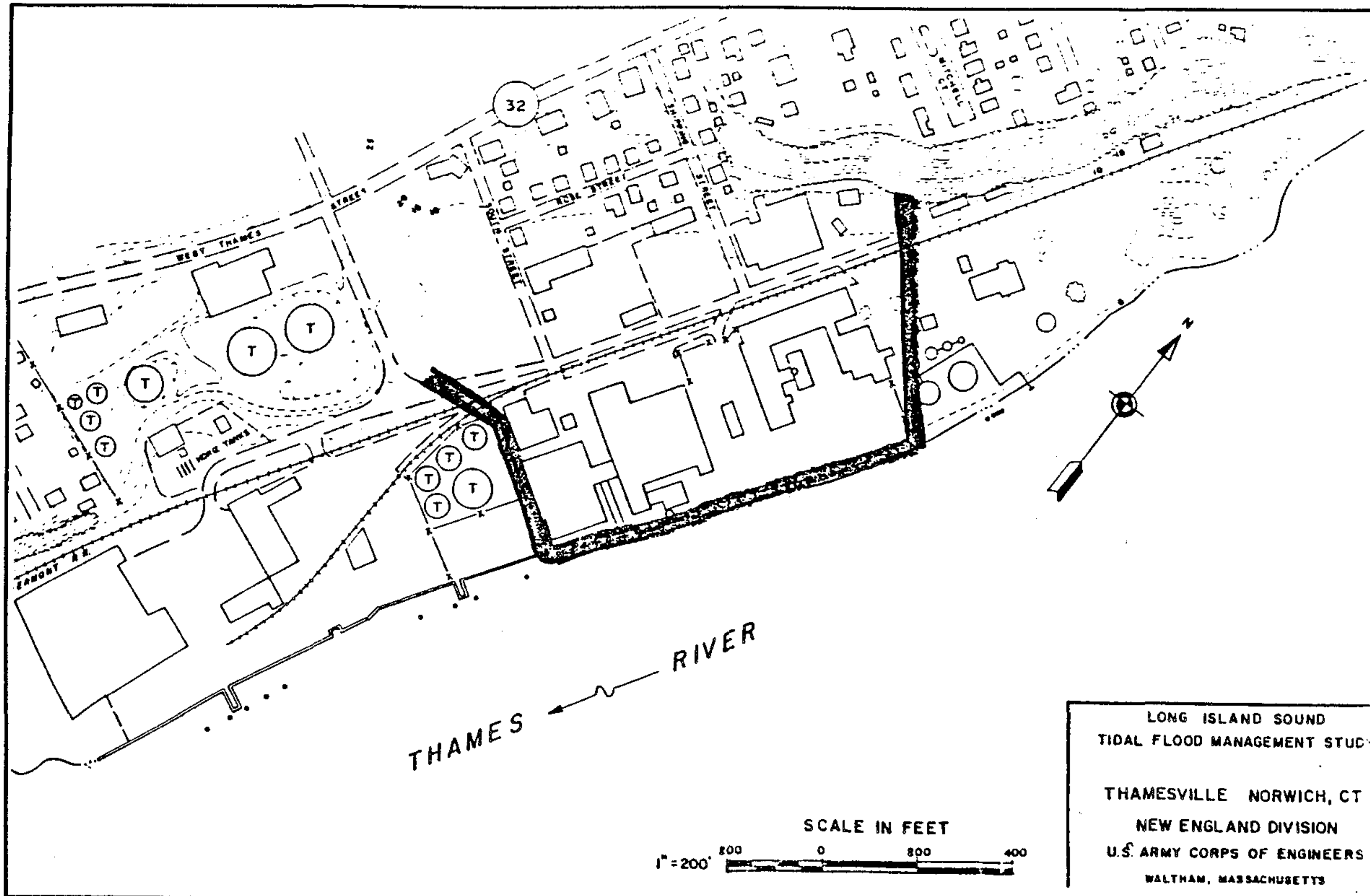

Figure 1.3-2 Alternative No. 3 - Floodwall (Waskiewicz, 1985)

TABLE 1.3-1
DESCRIPTION OF ALTERNATIVES FOR FLOOD DAMAGE REDUCTION (Waskiewicz, 1985)

Alternative	Area Protected	Description/Options
No. 1 - Floodproofing	Lehigh Petroleum Complex	
	o Office Building	o Keep water out through waterproofing walls and providing shielding for openings
		o Allow flooding - rearrange contents
	o Pump and Valves	o Elevate
		o Wall
	o Nutmeg Wire/ Abbott Seafoods	o Keep water out by floodproofing existing walls or constructing ring walls
		o Rearrange/raise machines and stock
		o Emergency removal of stored items
	o Oil Tanks	o Under analysis
	American Thermos Warehouse	o Keep water out
		o Move stored goods off the first floor to upper floors
No. 2 - Dike and Floodwall Construction	Entire project area	Construct dike and floodwall from Lehigh Gas and Connecticut Beverage Company to Lehigh Petroleum and Norwich Iron
No. 3 - Floodwall	Lehigh Petroleum, American Thermos and Sawyer Displays	Construct a floodwall from the high ground adjoining the railroad tracks around Sawyer Displays, American Thermos and Lehigh Petroleum

2.0 AFFECTED ENVIRONMENT

2.1 General Description of the Area

The Thames River is an estuarine river which extends some fifteen miles from Long Island Sound to the confluence of the Yantic and Shetucket Rivers. The river is maintained as a navigable channel from New London Harbor north to the City of Norwich, Connecticut. The overall Thames River basin contains nine major tributaries, and covers approximately 1,599 square miles within the States of Connecticut, Massachusetts and Rhode Island.

The community of Thamesville lies within the City of Norwich, Connecticut. Thamesville itself is primarily a cluster of commercial, industrial and residential properties located along the west bank of the Thames River (see Appendix A).

2.2 Geology, Topography and Soils

The geology of the Norwich, Connecticut area is characterized by granite-gneiss and schist bedrock overlain by glacial till and stratified drift. Bedrock lineations trend in a north-south to northeast-southwest direction. Glacial till (i.e., unsorted silty gravelly sand with cobbles and boulders) may be found in a thin layer over hills and a thicker layer in the valleys. Glacial meltwater deposited stratified sand and gravel over the till primarily in the valleys (NERBC, 1978 and Corps, 1981).

The topography of the State of Connecticut is predominately hilly. The terrain in the eastern half of the state ranges in elevation from 300 to 1,000 feet. Rolling hills and valleys dominate the topography of the general project area. Variations in the terrain range from the over 500 foot Plain Hill, the highest point in Norwich, to less than 10 feet in the Thamesville area along the floodplain of the Thames River (NOAA, 1982; NERBC, 1978 and Corps, 1981).

Soils within the area are highly variable in terms of depth, stoniness and rockiness. Area soils are well drained with the exception of soils which are underlain with hardpan or semipermiable substrata. The soils in upland areas and along slopes are generally stony to rocky; whereas, soils along the floodplain of the Thames River are for the most part free of stones (NERBC, 1978 and Corps, 1981). Soils within the study area are generally covered with up to several feet of fill.

2.3 Land Use

The City of Norwich contains a wide variety of land uses. There are approximately twenty different zoning or land use categories within the area, including: residential, commercial, industrial, open space and waterfront development (Norwich, 1983 and 1984).

Thamesville lies along the transition zone between the City of Norwich, Connecticut Town Consolidated District and City Consolidated District. Figures 2.3-1 and 2.3-2 show the zoning districts for the study area as designated by the City of Norwich Planning Department. These figures show that the project area has been classified as a heavy industrial zone bordered by general commercial and multi-family residential zones (Norwich, 1983 and 1984). Zoning maps for the entire City of Norwich accompany this report.

Within the Thamesville 36 acre project area there are approximately 40 buildings and storage tanks. These facilities have been categorized into the following groups:

- Residential - 24%
- Commercial - 29%
- Industrial - 47%.

The residential land use category includes both single and multi-family dwellings. The commercial and industrial categories include the following:

- Norwich Iron (salvage operation)
- United Metal (metal coating)
- Nutmeg Wire (wire fabrication)
- Abbot Seafood (storage of canned and packaged foods)
- American Thermos (storage)
- Sawyer Displays (manufacture of counters and displays)
- Dahl Oil (fuel oil storage and distribution)
- Lehigh Gas (bottled gas distribution and retail sales)
- Lehigh Petroleum (fuel oil storage and distribution)
- Connecticut Beverage Company (distribution)
- Sachem (fruit and produce company - wholesaler)
- DOCO (part of Dahl Oil - tires and lubricants)
- Sign Design (manufacture of signs)
- General Dynamics (storage) (Corps, 1981; Waskiewicz, 1985; HMM, 1985).

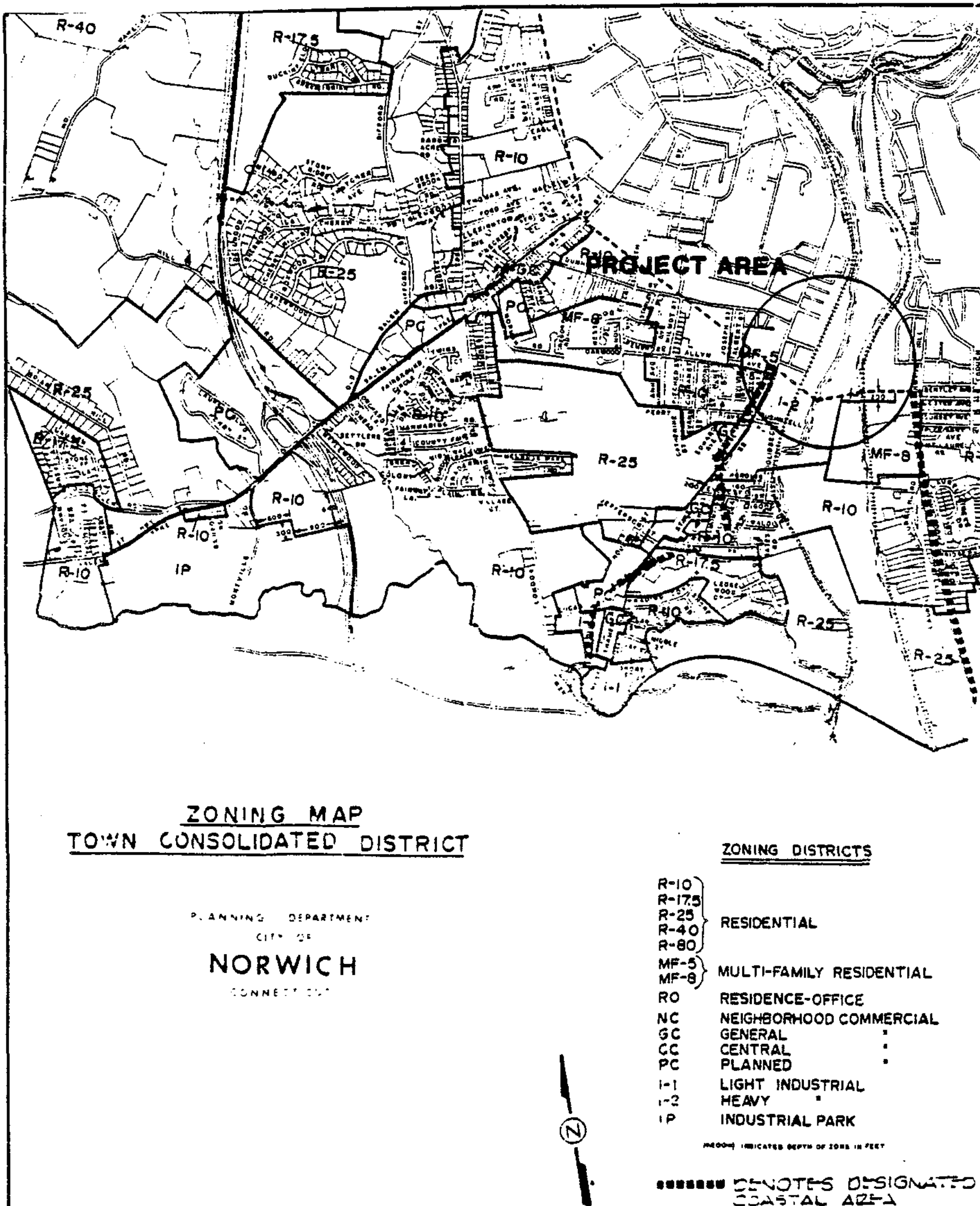

Figure 2.3-1 Town Consolidated District Zoning Map City of Norwich, Connecticut (City of Norwich, CT Planning Department, 1983)

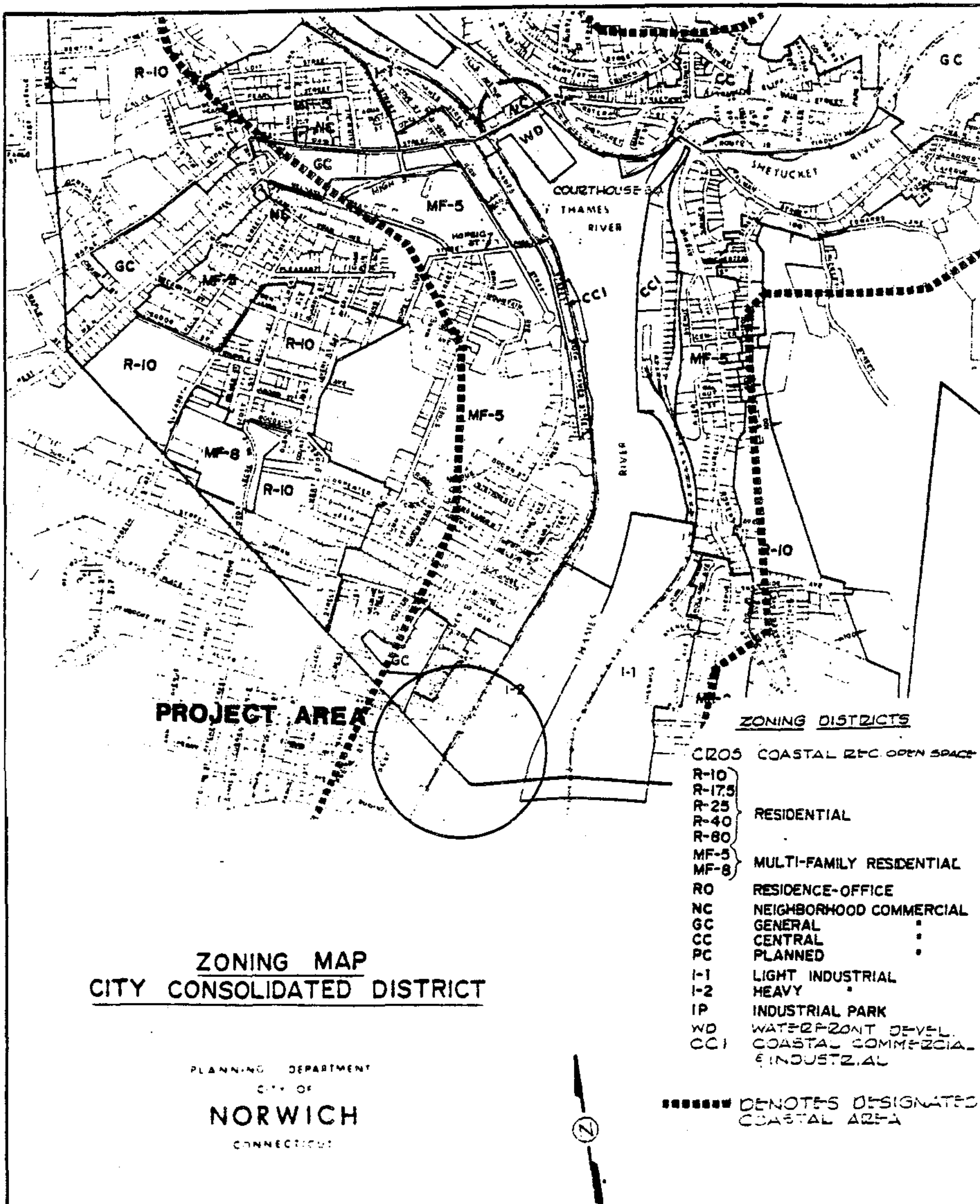

Figure 2.3-2 City Consolidated District Zoning Map City of Norwich, Connecticut (City of Norwich, CT Planning Department, 1984)

2.4 Climate

The Thamesville project area is located in southeastern Connecticut on the west bank of the Thames River approximately 14 miles inland of the Atlantic Ocean. The area is characterized as a flood plain with gentle rolling terrain to the west. The climate of the project area is greatly influenced by its location along the path of prevailing westerlies, a belt of generally eastward moving air. This circulation system contains extensive air masses from higher and lower latitudes which interact to produce low-pressure storm systems. A large number of these storm centers and air-masses cross over or by the state during the year such that roughly a twice a week alteration from fair to cloudy or stormy conditions occurs. This variability in weather patterns is generally accompanied by abrupt changes in temperature, moisture, sunshine and wind direction and speed. The chief characteristics of the area's climate are summarized as follows:

- o equable distribution of precipatation throughout the year,
- o large temperature ranges both on a daily basis and annually,
- o great variations in the same season or month in different years, and
- o diverse weather over short periods of time (NOAA, 1982).

Annual temperature in the Thamesville project area averages about 49°F, with an average daily range of 18°F. Temperatures range from an approximate average maximum of 80°F in July and August to an average minimum of 19°F in January. Summer temperatures average 68°F while in winter they average 28°F.

Annual precipitation in the project area is distributed rather evenly on a monthly basis. Approximately four inches (water equivalent) of precipitation occur each month, with an annual total of about 46 inches. Snowfall amounts in the Thamesville area average approximately 40 inches per year.

Precipitation occurrences are generally the result of local afternoon showers (sometimes accompanied by thunder and lightning) during the summer months, and moisture associated with low pressure centers (extratropical cyclones) which track over or near the project area during the months of September through May. In addition, tropical storms may affect the area during the months of August through October as they progress northward over the Atlantic Ocean. When a hurricane strikes the state full force, significant damage can occur as was evidenced by the recent Hurricane "Gloria" (September 27, 1985). A direct hit by such storms, however, is a rare occurrence. Aside from these storms the most serious weather hazard to the project area is extratropical coastal storms which impact the area much more frequently. These storms generate high winds and heavy rains, and can produce significant snowstorms when they occur in the winter. When tropical or extratropical coastal storms occur at the time of high tide, flooding and heavy damage can result in low lying areas (NOAA, 1979; NOAA, 1982).

2.5 Hydrology and Hydraulics

The Thames River basin drains 1,599 square miles in Connecticut, Massachusetts and Rhode Island. The overall Thames River drainage basin is comprised of ten sub-basins which are separated from each other by drainage divides. Thamesville lies within the Thames sub-basin, a 112 square mile area south of Norwich which is drained by the Thames River. Of the ten sub-basins which comprise the Thames River drainage basin, the Thames sub-basin is furthest downstream, thus it also receives stream flow from the other nine sub-basins. Near Thamesville, the average annual precipitation is approximately 46 inches/year. About 22 inches of precipitation is returned to the atmosphere by evaporation and transpiration. The remaining 24 inches of annual precipitation either flows overland to streams or percolates downward to the water table where, by groundwater flow, it discharges into surface waters (USFWS, 1984). During the winter months, the effects of evaporation and transpiration are reduced which may result in increased stream flows and slightly higher groundwater levels (NERBC, 1978). Runoff in the basin results in an average yield of 1.64 cubic feet per second (cfs) per square mile of drainage area in both direct runoff and groundwater outflow into surface waters (NERBC, 1978). At the confluence of the Shetucket River and the Yantic River, approximately 0.7 miles upstream of Norwich, annual flows average 530 billion gallons per year (2,247 cfs) (USFWS, 1984).

The general hydrogeology of the Thamesville area consists of glacial deposits overlying metamorphic and igneous bedrock. The glacial deposits are stratified drift, a coarse to medium sand with an average permeability estimated to be about 1,500 gallons per day per square foot (gpd/ft^2) and a saturated thickness of unconsolidated deposits of up to 40 feet (Thomas, *et al*., 1968).

The loss of water from the basin through consumption or diversions has not been large. Nor has man affected the amount of runoff in the basin to a measurable extent despite long-term and radical changes in land cover characteristics (NERBC, 1978). The most noticeable effort to regulate stream flow in the upper part of the basin is the construction of dams. Dams serve to store water for flood control, hydropower, recreation, water supply and other purposes.

Flooding in Thamesville may occur during any month of the year and may be a result of two entirely different processes: (1) Flooding is possible from interior drainage of the basin where runoff and groundwater outflow lead to increased stream flows. Flooding from interior drainage may occur during or after any significant precipitation event; however, spring floods are common as a result of melting snow and ice (NERBC, 1978). (2) The Thames River is estuarine, and flooding in Thamesville may also occur as a result of tidal influences. Tidal flooding may occur during any time of the year, but it can be most severe when a significant storm event is accompanied by high tide. Thamesville is susceptible to flooding from either of these phenomena or from a combination of the two; however the most significant floods at Thamesville have been tidal.

Tidal flooding generally takes place when coastal storms combine with incoming tides. The storms may be either tropical storms or extratropical storms such as the "northeasters" for which New England is known. The potential for flooding increases with increasing tidal surge. Flood levels are exacerbated with the combination of severe storm events and high astronomically predicted tides (the spring high tides in Norwich provide a tidal range of 6.0 feet versus the mean tidal range of 3.1 feet).

The flood of record for the Norwich area is the "Great New England" hurricane which occurred September 21, 1938. Tidal flood levels approached 14.5 feet (NGVD) in Thamesville during the 1938 hurricane. The second flood of record, Hurricane Carol, which occurred August 31, 1954, had tidal flood levels approaching 10 feet (NGVD) in Thamesville.

Nevertheless, the contribution of interior drainage to flooding at Thamesville is worthy of consideration, in light of the fact that the reservoirs and dams in the Thames River drainage basin are in the upper reaches of the drainage basin. Many of the dams and reservoirs are on tributaries of the Thames River which are as far upstream as the Massachusetts border. As a result, a considerable portion of the Thames River drainage basin is not controlled by dams and reservoirs (Mead, 1985). During high flow periods flood control reservoirs in the upper part of the basin may not effectively reduce or control stream flows as far downstream as Thamesville.

It is estimated that ~~severe~~ damage due to flooding would begin at about 7.0 feet (NGVD) in Thamesville ~~(USFWS, 1984)~~.

2.6 Water Quality

The Thames River Basin has been experiencing long-term degradation from approximately 65 significant municipal, domestic, institutional and industrial point source discharges, as well as non-point discharges such as urban runoff. Within the 15 mile stretch of the Thames River from Long Island Sound to Norwich, Connecticut 14 significant point source discharges have been identified (NERBC, 1978). One of the major water quality problems in the Thamesville area is the combined sewer overflows in the City of Norwich. With a small storm, stormwater runoff is combined with wastewater and generally conveyed to a treatment facility. However, with larger storms, the treatment facility cannot handle the added flow of water. In that case, the combined sewers overflow directly into the Thames River. The City of Norwich is implementing a phased program to correct the combined sewer overflow problem (NERBC, 1978; Major, 1985).

Under the State of Connecticut Water Quality Standards the Thames River has been classified as SC, from Norwich to Long Island Sound, due to combined sewer overflows, with a goal of SB. This SC classification indicates that the Thames is suitable for fish, shellfish and wildlife habitat; suitable for recreational boating and industrial cooling, and has good aesthetic value. In addition, specific standards have been promulgated for nine different parameters. Tables 2.6-1 and 2.6-2 present an overview of the water quality standards for SB and SC, respectively.

The U.S. Geological Survey conducts routine monitoring of the water quality of the Thames River. On a biweekly basis water samples are taken from the surface and the bottom of the river and analyzed for approximately 40 chemical and physical parameters. Appendix B presents an example of the type of water quality data available for the Thames River. These data indicate that the water quality is occasionally in contravention of the water quality standards for several parameters. For example, the level of dissolved oxygen in the water is periodically below the standard of four milligrams per liter (USGS, 1982). The State of Connecticut, Department of Environmental Protection, Water Compliance Unit does not monitor the Thames River water quality. It has not conducted any studies for water quality (Mason, 1985).

2.7 Aquatic Ecosystem

The Thames River estuary in the project area is subject to tidal fluctuation. The salt wedge extends up the Shetucket River to the Route 2 bridge in Norwich during summer low flows. When high freshwater inflow occurs with an ebbing tide, the head of the salt wedge may be pushed several kilometers downstream (Minta, 1980 and Minta, 1985). Estuarine systems are usually very productive. However, use of the Thames and its shoreline for industrial development, commercial navigation,

COASTAL AND MARINE WATERS

CLASS SB

Suitable for bathing, other recreational purposes, industrial cooling and shellfish harvesting for human consumption after depuration; excellent fish and wildlife habitat; good aesthetic value.

1. Dissolved oxygen	Not less than 5.0 mg/l at any time
2. Sludge deposits — solid refuse — floating solids, oils and grease — scum	None except for small amounts that may result from the discharge from a waste treatment facility providing appropriate treatment.
3. Sand or silt deposits	None other than of natural origin except as may result from normal agricultural, road maintenance, construction activity or dredge material disposal provided all reasonable controls are used.
4. Color and turbidity	A secchi disc shall be visible at a minimum of 1 meter, SBb — criteria may be exceeded. (See Note 6)
5. Coliform bacteria per 100 ml	Fecal coliform shall not exceed a log mean of 200 organisms/100 ml nor shall 10% of the samples exceed 400 organisms/100 ml.
6. Taste and odor	None in such concentrations that would impair any usages specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.
7. pH	6.8-8.5
8. Allowable temperature increase	None except where the increase will not exceed the recommended limit on the most sensitive receiving water use and in no case exceed 83 degrees F or in any case raise the normal temperature of the receiving water more than 4 degrees F. During the period including July, August and September, the normal temperature of the receiving water shall not be raised more than 1.5 degrees F unless it can be shown that spawning and growth of indigenous organisms will not be significantly affected. (See Note 19)
9. Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, or impair the water for any other usage assigned to this class. (See General Policy 11)

TABLE 2.6-1
CONNECTICUT WATER QUALITY STANDARDS FOR CLASS SB WATERS
(adapted from Connecticut Water Quality Standards and Classifications)

COASTAL and MARINE WATERS
CLASS SC

Suitable for fish, shellfish and wildlife habitat; suitable for recreational boating and industrial cooling, good aesthetic value.

1. Dissolved oxygen	Not less than 4 mg/l at any time.
2. Sludge deposits — solid refuse — floating solids, oils and grease — scum	None except for small amounts that may results from the discharge from a waste treatment facility providing appropriate treatment.
3. Sand and silt deposits	None other than of natural origin except as may result from normal agricultural, road maintenance, construction activity or dredge material disposal provided all reasonable controls are used.
4. Color and turbidity	None in such concentrations that would impair any usages specifically assigned to this class.
5. Coliform bacteria per 100 ml	Fecal coliform shall not exceed a log mean of 1,000 organisms/100 ml nor shall 10% of the samples exceed 2,500 organisms/100 ml.
6. Tastes and odor	None in such concentrations that would impair any usages specifically assigned to this class and none that would cause taste and odor in edible fish or shellfish.
7. pH	6.5-8.5
8. Allowable temperature increase	None except where the increase will not exceed the recommended limit on the most sensitive receiving water use and in no case exceed 83 degrees F or in any case raise the normal temperature of the receiving water more than 4 degrees F. During the period including July, August and September, the normal temperature of the receiving water shall not be raised more than 1.5 degrees F unless it can be shown that spawning and growth of indigenous organisms will not be significantly affected.
9. Chemical constituents	None in concentrations or combinations which would be harmful to human, animal or aquatic life or which would make the waters unsafe or unsuitable for fish or shellfish or their propagation, or impair the water for any other usage assigned to this class.

TABLE 2.6-2

CONNECTICUT WATER QUALITY STANDARDS FOR CLASS SC WATERS

(adapted from Connecticut Water Quality Standards and Classifications) and waste assimilation has lowered its productivity as compared to other estuaries (NERBC, 1981).

The river in the project area supports a diverse fish population including warm and cold freshwater species and some saltwater species (Minta, 1985). Principal fish species known to occur in this stretch of the river are listed in Table 2.7-1. There is a fishery for bluefish, snapper bluefish, Atlantic mackerel, Atlantic tomcod, striped bass, white catfish, American eel, rainbow smelt, alewife, and white perch from the Norwich area to Stoddard Hill State Park, approximately five miles downstream of the project area. The diverse fishery exists because many species migrate into the estuary for feeding (adults or juneviles), spawning, and use of nursery habitat (Whitworth et al., 1975 and Minta, 1985).

The Connecticut Department of Environmental Protection has placed high priority on the restoration of anadromous fish in the Thames River system (Minta, 1980). Historical records indicate that the drainage once supported runs of American shad, Atlantic salmon, and alewives. Studies have shown that restoration of adult American shad to the Thames River system produced fish to the base of Greenville dam, upstream from the project area. The effort proved the river system is suitable for supporting this species. However, fishway facilities must be constructed at the dam since the shad cannot sustain themselves in the lower part of the river system. Similar studies have been done with sea-run brown trout. Projections indicate that under proper conditions, it would be possible to create a recreational fishery for shad nearly equal to that existing in the Connecticut portion of the Connecticut River (Minta, 1980).

The Thames River has been listed in an Alternative Action Plan for salmon resotration. There is, however, no stocking of Atlantic salmon at present (USFWS, 1984 and Minta, 1985).

Sea-run brown trout smolts have been stocked upstream from the project area since 1971 as part of an evaluation for Atlantic salmon stocking. Adults have been recorded approximately one mile upstream from the project area at the base of the Greenville dam, the lowermost dam on the Shetucket River in the town of Norwich (Minta, 1980).

The lower portion of the Thames River estuary supports some shellfish populations. The blue crab, *Callinectes sapidus*, is making a comback and provides a small recreational fishery. The lower portion of the estuary also produces the American oyster, *Crassostrea virginica*, hard-shell clams, *Mercenaria mercenaria*, and soft-shell clams, *Mya arenaria*, but they are not taken for direct consumption due to high coliform counts (Corps, 1981 and Blake and Smith, 1984). Readily available data do not indicate the nature of shellfish populations or those of other benthos in the project area, located in the upper portion of the estuary.

TABLE 2.7-1
FISH SPECIES FOUND IN THE THAMES RIVER IN THE PROJECT AREA
(CT, Undated a & b; USFWS, 1984: Whitworth *et al.*, 1975
and Whitworth *et al.*, 1976)

Common Name	Scientific Name
PETROMYZONTIDAE - Lampreys	
Sea Lamprey	*Petromyzon marinus*
ANGUILLIDAE - Freshwater Eels	
American Eel	*Anguilla rostrata*
CLUPEDIAE - Herrings	
American Shad	*Alosa sapidissima*
Alewife	*Alosa pseudoharengus*
SALMONIDAE - Trouts	
Sea Run Brown Trout	*Salmo trutta*
OSMERIDAE - Smelts	
Rainbow Smelt	*Osmerus mordax*
ESOCIDAE - Pikes	
Chain Pickerel	*Esox niger*
CYPRINIDAE - Minnows and Carps	
Carp	*Cyprinus carpio*
Golden Shiner	*Notemigonus crysoleucas*
Common Shiner	*Notropis cornutus*
Spottail Shiner	*Notropis hudsonius*
Blacknose Dace	*Rhinichthys atratulus*
Longnose Dace	*Rhinichthys cataractae*
Fallfish	*Semotilus corporalis*
CATOSTOMIDAE - Suckers	
White Sucker	*Catostomus commersoni*
ICTALURIDAE - Freshwater Catfishes	
Brown Bullhead	*Ictalurus nebulosus*
White Catfish	*Ictalurus catus*
CYPRINODONTIDAE - Killifishes	
Banded Killifish	*Fundulus diaphanus*
Mummichog	*Fundulus heteroclitus*
Striped Killifish	*Fundulus majalis*

TABLE 2.7-1 (Cont'd)
FISH SPECIES FOUND IN THE THAMES RIVER IN THE PROJECT AREA
(CT, Undated a & b; USFWS, 1984: Whitworth *et al.*, 1975
and Whitworth *et al.*, 1976)

Common Name	Scientific Name
GASTEROSTEIDAE - Sticklebacks	
Threespine Stickleback	*Gasterosteus aculeatus*
Fourspine Stickleback	*Apeltes quadracus*
PERCICHTHYIDAE - Temperate Basses	
White Perch	*Morone americana*
Striped Bass	*Morone saxatilis*
CENTRARCHIDAE - Sunfishes	
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis Macrochirus*
Largemouth Bass	*Micropterus salmoides*
Black Crappie	*Pomoxis nigromaculatus*
PERCIDAE - Perches	
Yellow Perch	*Perca flavescens*
LABRIDAE - Wrasses	
Tautog	*Tautoga onitis*
POMATOMIDAE - Bluefish	
Bluefish	*Pomatomus saltatrix*
SCOMBERIDAE - Mackerels	
Atlantic Mackerel	*Scomber scombrus*
GADIDAE - Cod	
Atlantic Tomcod	*Microgadus tomcod*

2.8 Terrestrial Ecosystem

Within the Thames River Basin there are over 70,000 acres of public lands. These lands provide both habitat for terrestrial resources and recreational opportunities (see Section 2.13). The segment of the basin which lies within the State of Connecticut contains 12 wildlife management areas that encompass approximately 40,000 acres (NERBC, 1978). These areas support a variety of habitat types ranging from forested uplands to wetlands.

The Thames River area has been heavily urbanized. Residential, commercial and industrial developments have been located along the banks of the river. The Thamesville project area is completely developed. There are no forested areas within the project area. The only wetland resource within the general area is the Thames River itself. Vegetation is limited to landscaped areas, ornamental plantings, gardens and isolated pockets of plant growth along fences, buildings, and storage areas. Table 2.8-1 contains a summary listing of vegetation identified within the project area.

There are no wildlife management areas, refuges or preserves within the study area (Maroncelli, 1985). Since this area is highly developed it is unlikely that there is a high diversity of terrestrial wildlife. Mammalian wildlife which typically occurs within an urban environment such as the Thamesville area include: rabbits (Sylvilagus floridanus), squirrels (Sciurus carolinensis or Tamiasciurus hudsonicus) and rodents (e.g., Rattus norvegicus) In addition, there are a number of mammals which are mobile, are not site specific, and which have fairly large ranges. Due to these characteristics the State of Connecticut, Department of Environmental Protection, Wildlife Bureau (Maroncelli, 1985) has indicated that any or all of the following species may occur within the project area:

o Beaver	Castor canadensis
o River Otter	Lutra canadensis
o Mink	Mustela vison
o Muskrat	Ondatra zibethica
o Striped Skunk	Mephitis mephitis
o Bobcat	Lynx rufus
o Raccoon	Procyon lotor
o Virginia Opossum	Didelphis marsupialis
o Short-tailed Weasal	Mustela erminea
o Longtail Weasel	Mustela frenata
o Coyote	Canis latrans
o Red Fox	Vulpes vulpes
o Gray Fox	Urocyon cinereoargentes

However, due to the highly developed urban environment surrounding the project area, it is unlikely that species such as the bobcat or coyote would be found in Thamesville.

TABLE 2.8-1
VEGETATION IDENTIFIED WITHIN THE PROJECT AREA

Common Name	Scientific Name
Apple	*Malus* sp.
Aspen	*Populus* sp.
Birch	*Betula* sp.
Black Swallowwort	*Cynanchum nigrum*
Black-eyed Susan	*Rudbeckia hirta*
Catalpa	*Catalpa speciosa*
Cattail	*Typha latifolia*
Chicory	*Cichorium intybus*
Common Milkweed	*Asclepias syriaca*
Common Plantain	*Plantago major*
Common Ragweed	*Ambrosia artemisiifolia*
Common St. Johnswort	*Hypericum perforatum*
Elderberry	*Sambucus canadensis*
Goldenrod	*Solidago* sp.
Grape	*Vitis* sp.
Grass	*Gramineae* sp.
Grass	*Poaceae* sp.
Horsetail	*Equisetem* sp.
Japanese Knotweed	*Polygonum cuspidatum*
Joe-Pye-Weed	*Eupatorium* sp.
Locust	*Gleditsia* sp.
Maple	*Acer* sp.
Mountain-Ash	*Sorbus* sp.
Oak	*Quercus* sp.
Phlox	*Phlox* sp.
Poison Ivy	*Rhus radicans*
Red Clover	*Trifolium pratense*
Rose	*Rosa* sp.
Sumac	*Rhus* sp.
Thistle	*Cirsium* sp.
Tree-of-Heaven	*Ailanthus altissima*
Virginia Creeper	*Parthenocissus quinquefolia*
Wild Carrot	*Daucus carota*
Willow	*Salix* sp.

As part of the Audubon Society's Breeding Bird Atlas a number of surveys have been conducted within the Norwich (i.e., Breeding Bird Atlas Block 072E) area during the past four years. Table 2.8-2 contains a summary listing of confirmed, probable and possible breeding birds within approximately two miles of the Thamesville project area (Rosgen, 1985 and Dewire, 1985). Specific information on migratory birds, waterfowl and wintering populations in the project area is not available in the literature.

2.9 Ecologically Significant Species

The Thames River Basin contains a number of ecologically significant species. The river basin lies within the Atlantic Flyway for migrating birds and serves as the pathway for anadromous fish species.

Within the highly developed urban project area there are three distinct groups of ecologically significant species: songbirds, raptors and anadromous fish. Songbirds are highly valued for their beauty and considered a passive recreational resource. Of particular concern in the Eastern bluebird (*Sialia sialis sialis*) which has been experiencing a marked decline in population. The species is making a comeback in the region, and is a confirmed breeding bird within approximately two miles of the project area. Raptors are also considered a valuable resource. The American kestrel (*Falco sparverius*) and broad-winged hawk (*Buteo platypterus*) both have been sighted and may be breeding within two miles of the project area. As it was previously indicated anadromous fish species such as shad, (*Alosa sapidissima*) and sea run brown trout (*Salmo trutta*) have been stocked in the Thames. In addition, plans are being considered to restore the Atlantic Salmon (*Salmo salar*) (USFWS, 1984 and Minta, 1985).

2.10 Rare, Threatened and Endangered Species

No extant populations of rare, threatened or endangered species have been identified within the general project area. As the project area lies within the Atlantic Flyway the potential exists for an occasional protected bird species which is migratory (e.g., bald eagle - *Haliaeetus leucocephalus* or peregrine falcon - *Falco peregrinus*) to cross through, rest or feed within the area (Corps, 1981; Murray, 1985; Lang, 1985).

2.11 Socioeconomic

The socioeconomic status of the City of Norwich has historically and continues to be closely linked to its geographic location. The two geographic components which have strongly influenced the City are its location at the junction of the Yantic, Shetucket and Thames Rivers just 15 miles from Long Island Sound, and its position between the metropolitan areas of New York and New England.

TABLE 2.8-2
CONFIRMED, PROBABLE AND POSSIBLE BREEDING BIRDS IDENTIFIED WITHIN THE PROJECT AREA

Common Name	Scientific Name
American Goldfinch	*Carduelis tristis*
American Kestrel, Sparrow Hawk	*Falco sparverius*
American Robin	*Turdus migratorius*
Bank Swallow	*Riparia riparia*
Barn Swallow	*Hirundo rustica*
Black-capped Chickadee	*Parus atricapillus*
Blue Jay	*Cyanocitta cristata*
Blue-winged Warbler	*Vermivora pinus*
Broad-winged Hawk	*Buteo platypterus*
Cedar Waxwing	*Bombycilla cedrorum*
Chimney Swift	*Chaetura pelagica*
Chipping Sparrow	*Spizella passerina*
Common Flicker	*Colaptes auratus*
Common Grackle	*Quiscalus quiscula*
Downy Woodpecker	*Picoides pubescens*
Eastern Bluebird	*Sialia sialis sialis*
Eastern Wood Pewee	*Contopus virens*
House Finch	*Carpodacus mexicanus*
House Wren	*Troglodytes aedon*
Mallard	*Anas platyrhynchos*
Northern Oriole	*Icterus galbula*
Ovenbird	*Seiurus aurocapillus*
Red-eyed Vireo	*Vireo olivaceus*
Red-winged Blackbird	*Agelaius phoeniceus*
Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Rufous-sided Towhee	*Pipilo erythrophthalmus*
Scarlet Tanager	*Piranga olivacea*
Song Sparrow	*Melospiza melodia*
Starling	*Sturnus vulgaris*
Tree Swallow	*Iridoprocne bicolor*
Tufted Titmouse	*Parus bicolor*
Veery	*Catharus fuscescens*
Yellow Warbler	*Dendroica petechia*

Socially the Norwich area provides urban, suburban and rural characteristics, with easy access to major metropolitan centers. The City's wealth, beauty and affluence in the 19th century earned it the nickname "The Rose City," which has continued to this day. The community has a large number of cultural, historical and recreational facilities (see Section 2.13).

Historically, the City's economy has been closely tied to its location along the water. Initially area waterways served as transportation routes for shipping and trading. By the late 1700's Norwich was one of the largest cities in the colonies. With the advent of industrialization, the avaiability of water for processing, power and transportation played a large part in Norwich's economic growth. Transportation has continued to play a role in the area's growth as the City of Norwich has ready access to a number of major highways (e.g., I-95, I-86, I-395, and Route 2) as well as major international airports in Hartford, Boston, and New York. Currently, southeastern Connecticut's economic strength is primarily due to defense activities located along the Thames estuary (Corps, 1981 and SCRPA, 1984).

During the past ten years employment in defense activities has grown. Primary defense activities account for approximately one-third of the area's employment. It is estimated that at least 50% of the total work force in southeastern Connecticut is employed in defense activities if secondary and indirect aspects are considered. Throughout the past decade the region's unemployment rate was lower than the national average and the national recession of the early 1980's had substantially less impact because of defense related employment. The defense industry is considered largely responsible for the area's economic health, the high growth rate of area communities, and as its greatest potential long-term economic problem (SCRPA, 1984 and Corps, 1981). It is considered a potential problem because the economy of the area is both directly and indirectly dependent upon the defense industry, and reductions or changes in the defense industry would have subsequent impacts on the economy.

2.12 Air Quality and Noise

Air quality of the Norwich area is routinely monitored at a number of locations. Monitors for various air quality parameters are located in the following communities:

- Norwich - Particulates
- Preston-Sulfur dioxide (SO_2)
- Groton - Ozone, SO_2 and Particulates

The air quality of Norwich is in attainment (i.e., the ambient air quality meets the national standards for a given pollutant as established by the U.S. Environmental Protection Agency) for the parameters of SO_2, nitrogen dioxide (NO_2) and lead. The air quality is in non-attainment for the secondary standard for total suspended particulates (Cartolano, 1985).

The noise levels within the area are typical of those for any urban area. Noise levels range from 42 decibels (dB) to 68 dB in a suburban residential area next to railroad tracks (Wyle, 1971). Higher noise levels would be experienced in such areas as construction zones or where heavy equipment is utilized.

2.13 Recreation

The greater Norwich area has a wide range of recreational facilities. Recreational resources range from museums and historic sites to libraries and parks. There is a municipal wharf and a 230 slip marina is under construction along the Thames River. Fishing is popular in areas along the Thames (see Section 2.7). Public golf courses, tennis courts and playgrounds are located throughout the region. Area planning has included the development of new recreational facilities such as baseball fields, tennis and basketball courts, and playgrounds.

Within the project area there is no recreational access to the Thames River. The property is posted and access is restricted by fencing, the railroad tracks and commercial/industrial facilities. Adjacent to the study area is a neighborhood playground at the intersection of West Thames Street and South Street.

3.0 ENVIRONMENTAL IMPACTS

The proposed alternative actions have been assessed with respect to their environmental consequences on area resources. Both short-term and long-term impacts were evaluated. The following types of impacts were addressed:

- o beneficial impacts,
- o adverse impacts,
- o direct impacts, and
- o indirect impacts.

3.1 Alternative No. 1 - Floodproofing

As was previously indicated in Section 1.3 floodproofing would involve flood damage reduction for the Lehigh Petroleum Complex and the American Thermos Warehouse. Alternative measures considered include:

- o waterproofing walls,
- o shielding openings,
- o constructing ring walls,
- o elevation of equipment and stock, and
- o emergency removal of stored items.

Potential impacts are summarized in Table 3.1-1.

3.1.1 Geology, Topography and Soils

This alternative would have essentially no impacts on the geology, topography and soils of the project area or the surrounding area. Floodproofing would primarily involve alterations to existing structures and would not necessitate large scale excavation or spoil disposal.

3.1.2 Land Use

Alternative No. 1 would have minimal impacts on land use as only a segment of the project area would be affected. The potential does exist for a change in the utilization of existing facilities with floodproofing. The American Thermos Building is currently on the real estate market. With floodproofing this building could more readily be converted from warehousing to other uses.

TABLE 3.1-1
SUMMARY OF POTENTIAL IMPACTS ASSOCIATED WITH
ALTERNATIVE NO. 1 - FLOODPROOFING

Parameter	Type of Impact	
	Short-term	Long-term
Geology, Topography & Soils	o	o
Land Use	o	o
Climate	o	o
Hydrology and Hydraulics	o	o
Water Quality	o	o
Aquatic Ecosystem	o	o
Terrestrial Ecosystem	o	o
Ecologically Significant Species	o	o
Rare, Threatened & Endangered Species	o	o
Socioeconomic	-	+
Air Quality and Noise	-	o
Recreation	o	o

\+ Beneficial Impacts
o Little or No Impacts
\- Adverse Impacts

3.1.3 Climate

This alternative would not affect the climate of the area.

3.1.4 Hydrology and Hydraulics

Alternative No. 1 would not affect the hydrology and hydraulics of the Thames River area. Floodproofing activities would be focused on existing structures and should not impact surface runoff. No construction would occur along the banks or within the river.

3.1.5 Water Quality

The water quality of the Thames River would continue at its present level of classification under Alternative No. 1. No construction would take place immediately adjacent to the river. With ring walls, and other floodproofing measures the potential does exist for less debris and pollutants to enter the water in the advent of flooding. Materials which normally would be introduced into the water during a flood event would be protected and/or moved out of the reach of flood waters. In addition, floodproofing could prevent an oil spill from the Lehigh Petroleum Complex during a flood event.

3.1.6 Aquatic Ecosystem

As with the water quality this alternative action would have no significant impact on the aquatic ecosystem of the Thames River. Fishery resources and aquatic biota would not be affected as no construction would take place along the banks or within the Thames River. The containment of potential pollutants during a flood event would be a beneficial impact for the aquatic ecosystem.

3.1.7 Terrestrial Ecosystem

The area surrounding the Lehigh Petroleum Complex and American Thermos Warehouse is completely developed. The only vegetation which exists in this area is along cracks in the pavement and fences. Wildlife utilization of this area most likely is very low. Subsequently, the impacts of floodproofing would be insiginificant.

3.1.8 Ecologically Significant Species

Ecologically significant species would not be affected by the floodproofing (Alternative No. 1). Due to the highly developed nature of this segment of the project area it is unlikely that any significant species utilize it.

3.1.9 Rare, Threatened and Endangered Species

Except for possible migrants, no rare, threatened or endangered species utilize the project area. Any migratory species which could pass through the area or briefly stop at it should not experience any adverse impacts with Alternative No. 1.

3.1.10 Socioeconomic

The socioeconomic impacts of Alternative No. 1 would be limited to that segment of the project area which would be floodproofed. Short-term economic impacts would be experienced through the costs associated with floodproofing and the possible disruption of services. Long-term economic benefits would be realized through potential changes in property values and insurance ratings from floodproofing, and in the advent of significant flooding.

3.1.11 Air Quality and Noise

During the construction and implementation of floodproofing there would be minor adverse impacts on the air quality associated with the transportation of supplies and operation of heavy equipment. These impacts would be relatively insignificant. There would be no long-term air quality impacts from floodproofing.

The impacts of Alternative No. 1 on noise would be essentially the same as those associated with air quality. As this area is currently utilized for the transport of oil by trucks the transport of construction materials by trucks would be an insignificant increment. The operation of a backhoe or similar heavy duty equipment during the construction of any ring walls would cause a short-term increase in the noise level. There would be no long-term noise impacts from this alternative action.

3.1.12 Recreation

The floodproofing alternative would not affect recreation within the area. In addition, the various floodproofing alternative actions would not be apparent to recreationalists boating or fishing along the Thames River.

3.2 Alternative No. 2 - Dike and Floodwall Construction

Under Alternative No. 2 an earthen dike and concrete floodwall would be constructed. This alternative action calls for the construction of 2,300 feet of earthen dike, 200 feet of concrete floodwall, 750 feet of concrete bulkhead, a pumping station and other appurtenant structures (Corps, 1981). Potential impacts are summarized in Table 3.2-1.

3.2.1 Geology, Topography and Soils

This alternative would have a small impact on the geology, topography and soils of the project area and the greater Norwich area. The soil and rock necessary to construct the required earthen dike and concrete floodwall would have to be

TABLE 3.2-1
SUMMARY OF POTENTIAL IMPACTS ASSOCIATED WITH
ALTERNATIVE NO. 2 - DIKE AND FLOODWALL CONSTRUCTION

Parameter	Type of Impact	
	Short-term	Long-term
Geology, Topography & Soils	o	o
Land Use	o*	+
Climate	o	o
Hydrology and Hydraulics	o	o
Water Quality	-	+
Aquatic Ecosystem	-	+
Terrestrial Ecosystem	o*	+
Ecologically Significant Species	o*	+
Rare, Threatened & Endangered Species	o*	o
Socioeconomic	-	+
Air Quality and Noise	-	o
Recreation	-	o

\+ Beneficial Impacts
o Little or No Impacts
\- Adverse Impacts
* Possibly adverse impacts (-) depending on soil, gravel and stone excavation and spoil disposal site locations.

excavated from a site in the greater Norwich area and transported to the project area. This would cause a small change in the topography of both the excavation site and the project area. The construction of a 2,300 foot long dike, a maximum of 50 feet in height above the river bottom, 10 feet wide at the top with a slope ranging from 1 on 1.5 on the riverside to 1 on 2 on the landside would require approximately 200,000 cubic yards of soil, gravel and stone. In addition, construction would require the removal, transport and disposal of approximately 100,000 cubic yards of excavated and dredged material (Corps, 1981). This could have a small impact on the disposal site, if upland disposal is selected. Spoil disposal may also be contingent upon the chemical content of the spoil. The potential exists for the spoil to be contaminated with pollutants which would require special procedures for excavation, transport and disposal.

3.2.2 Land Use

Alternative No. 2 would have the potential for primarily beneficial impacts on the land use in the area. Portions of the site are vacant and underutilized. With the beneficial effects of adequate flood protection this land could be converted to any number of uses (see accompanying zoning maps). In addition, the potential exists for a change in utilization of existing facilities with flood protection. The potential, however, exists for land uses at the excavation site for the soil, gravel and stone and the disposal site for the spoil (if upland disposal is selected) to be adversely affected.

3.2.3 Climate

This alternative would entail no significant changes for the climate of the area.

3.2.4 Hydrology and Hydraulics

Preliminary alignments of the earthen dike and floodwall indicates that they will involve excavation and fill along the banks and into the Thames River. This would have impacts on the hydraulics of the Thames River.

The excavation of spoil and placement of fill would have the potential to affect the depth and configuration of the river on its western side and, thus, water flows in that area. In addition, the dike and floodwall will inhibit surface runoff to the Thames, of particular importance during flooding. To control this problem a pumping station would be constructed. The outfall from the pumping station could have some minor effects on the hydraulics of the river. At the soil, gravel and stone excavation site the removal of approximately 200,000 cubic yards of material could potentially affect the local hydrology. Impacts would be contingent upon the size and depth of the area excavated, and whether or not the area is quickly graded and revegetated. Hydraulic impacts could occur at the spoil disposal site, depending upon the disposal location selected for the 100,000 cubic yards of excavated and dredged material.

3.2.5 Water Quality

The excavation and placement of fill along the banks and into the Thames River as well as the operation of a pumping station during flood events have the potential to have adverse impacts upon water quality. Excavation of soil and dewatering could introduce pollutants trapped in the substrate into the water column, increase the levels of dissolved solids and turbidity, and decrease the level of oxygen in the water. The placement of fill could have similar impacts on water quality. The operation of the pumping station could have a number of impacts, including resuspension of settled solids and addition of pollutants. In the long-term, the stabilization of the bank, which is eroding in several locations, could enhance water quality adjacent to the project area.

3.2.6 Aquatic Ecosystem

Alternative No. 2 could also have adverse impacts upon the aquatic ecosystem. Impacts on water quality may be very closely correlated to impacts on the aquatic ecosystem. The excavation and placement of fill along the Thames River could affect benthos, finfish and other aquatic biota. For example, increases in turbidity affect light penetration and subsequently the biological productivity of phytoplankton which are a primary food source for many aquatic organisms. In addition, both the excavation of soil at the borrow site and disposal of spoil have the potential to affect aquatic resources if they are present at these sites.

3.2.7 Terrestrial Ecosystem

The construction of 2,300 feet of dike with a grassy slope on the landside would provide potential habitat for a number of terrestrial wildlife species and ecologically significant species (i.e., the bluebird, broad-winged hawk and kestrel). The slope of the dike would provide a significant amount of new habitat in a highly developed area. In addition, the dike could be managed to increase its value as habitat for wildlife.

Potentially adverse impacts could occur at the soil excavation site if a significant area were devegetated during the removal of soil, gravel and stone. In addition, depending upon disposal site location, the disposal of material excavated and dredged during the construction of the dike and wall could cover vegetation and wildlife habitat, and cause impacts.

3.2.8 Ecologically Significant Species

The excavation of spoil and construction of the dike and walls could have short-term adverse impacts on anadromous fish species. As previously indicated the water quality and aquatic ecosystem could be adversely affected by construction activities. If the dike were managed correctly and nesting boxes and platforms were erected the dike could be very beneficial to the bluebird, broad-winged hawk and kestrel (Rosgen, 1985).

This alternative could affect ecologically significant species at the spoil disposal site and the soil excavation site. Impacts to species outside of the project area, however, cannot be projected at this time as a spoil disposal site and soil excavation site have not been selected.

3.2.9 Rare, Threatened and Endangered Species

There are no rare, threatened or endangered species within the project are which would be affected by Alternative No. 2.

As with ecologically significant species the potential does exist to have adverse impacts on rare, threatened and endangered species if they occur at the spoil disposal site or soil excavation site.

3.2.10 Socioeconomic

The impacts of Alternative No. 2 on the socioeconomic environment would be diverse. Economic impacts associated with the costs of implementing this alternative and the disruption and possible displacement of services could be experienced throughout the short-term time period and extend into the long-term period. In addition, the costs associated with maintaining dikes and floodwalls of this magnitude should also be considered. However, it is probable that flood protection would increase the property value of the Thamesville project area and cause reductions in insurance premiums. The earthen dike and concrete floodwall could obscure the Thames River vista of area residents.

3.2.11 Air Quality and Noise

Construction related impacts would be likely. With an average size truckload of 15 cubic yards it is estimated that it would take 7,000 truckloads to remove all the spoil. The soil, gravel and rock necessary to construct the dike would require approximately 13,300 truckloads of material. The numbers of trucks would disrupt local businesses and traffic, adversely affect air quality and noise, and impact other environmental resources throughout the short-term construction time period. The potential does exist to utilize barges to transport spoil and soil; however, the highly developed nature of the Thames River and absence of a nearby supply source makes this unlikely.

Once the flood protection facilities were constructed there would be potential for minor impacts associated with the maintenance and operation of the pumping station and earthen dike. For example, periodic tests of equipment and mowing of slopes would temporarily increase noise levels. The dike and floodwall would also serve as a sound barrier and could potentially reflect project area noises towards adjacent residential neighborhoods.

3.2.12 Recreation

In general, Alternative No. 2 would have no significant, direct impacts on area recreation. The transport of materials to and from the site could indirectly affect utilization of area recreational resources (e.g., traffic, noise, dust). In particular, the neighborhood park at the intersection of West Thames Street and South Street would be affected by project activities.

The potential exists for area fishing and boating to be disrupted during the excavation of spoil and construction of the dike. In addition, recreationalists along the Thames River would see the dike and walls instead of the project area, but this should not detract from passive recreational use. If the area is managed for wildlife habitat and nesting boxes and platforms are constructed there would be positive benefits for passive recreation such as bird watching.

3.3 Alternative No. 3 - Floodwall

This alternative action is similar in nature to Alternative No. 1 in that only a segment of the site would be protected from flood damages. Lehigh Petroleum, American Thermos and Sawyer Displays would be surrounded by a floodwall. Two levels of flood protection have been considered: a 20 year storm and a 100 year storm. The 20 year storm would require flood protection to elevation 10 with a floodwall up to five feet in height. Flood protection for a 100 year storm would require protection to elevation 13.4 with a floodwall up to eight feet in height (Waskiewicz, 1985). The differences in the impacts associated with constructing a floodwall with a maximum height of five feet as opposed to a floodwall with a maximum height of eight feet are for the most part insignificant, with the exception of cost. Therefore, environmental impacts have been assessed for the construction of a floodwall in general. Potential impacts are summarized in Table 3.3-1.

3.3.1 Geology, Topography and Soils

Alternative No. 3 would have essentially no impact on the geology, topography and soils of the project area or the surrounding area.

TABLE 3.3-1
SUMMARY OF POTENTIAL IMPACTS ASSOCIATED WITH
ALTERNATIVE NO. 3 - FLOODWALL CONSTRUCTION

Parameter	Type of Impact	
	Short-term	Long-term
Geology, Topography & Soils	o	o
Land Use	o	o
Climate	o	o
Hydrology and Hydraulics	o	o
Water Quality	o	o
Aquatic Ecosystem	o	o
Terrestrial Ecosystem	o	o
Ecologically Significant Species	o	o
Rare, Threatened & Endangered Species	o	o
Socioeconomic	-	+
Air Quality and Noise	-	o
Recreation	o	o

+ Beneficial Impacts
o Little or No Impacts
- Adverse Impacts

3.3.2 Land Use

Alternative No. 3 should have minimal impacts on the land use of the project area as only a segment would be affected. With flood damage protection the potential does exist for a change in the utilization of the existing facilities. As previously indicated the American Thermos Building is on the real estate market and other areas of the site are vacant or underutilized. With flood protection these areas may be converted to more active uses.

3.3.3 Climate

This alternative would not affect the climate of the area.

3.3.4 Hydrology and Hydraulics

The construction of a floodwall would have impacts on the hydrology and hydraulics of the project area. Portions of the floodwall would be constructed along the bank of the Thames River and could extend into the river. This may require excavation of spoil in some areas which would have similar, but less extensive, impacts to those previously discussed under Alternative No. 2. The floodwall itself would affect surface runoff in the protected area (i.e., around Lehigh Petroleum, American Thermos and Sawyer Displays); however, cummulative impacts on the entire project area should be insignificant.

3.3.5 Water Quality

No changes in water quality would be expected due to Alternative No. 3. The alignment of the floodwall would follow the existing shoreline and could extend into the edge of the river. During the short-term construction time period the water quality level may be perturbed by construction activities. Over the long-term the floodwall could have beneficial impacts by stabilizing the existing bank which in areas is eroding into the river.

3.3.6 Aquatic Ecosystem

The impacts of Alternative No. 3 on the aquatic ecosystem would be essentially the same as those described above for water quality. During the short-term construction time period there could be minor adverse impacts associated with construction related activities. Over the long-term, aquatic resources should not be significantly affected by the floodwall.

3.3.7 Terrestrial Ecosystem

As previously indicated the Lehigh Petroleum Complex, American Thermos and Sawyer Display area is completely developed. Vegetation is confined to cracks in the pavement, along the edges of buildings and fences, and in landscaped areas. Wildlife utilization in this area is probably very low because of the lack of habitat. Therefore the impacts associated with the construction of a floodwall on the terrestrial environment would be insignificant.

3.3.8 Ecologically Significant Species

It is unlikely that any significant terrestrial species would utilize this area due to its lack of habitat and highly developed nature. Anadromous fisheries could experience minor short-term effects from construction-related impacts to water quality. In general, ecologically significant species would not be adversely affected by this alternative action.

3.3.9 Rare, Threatened and Endangered Species

As previously discussed there are no rare, threatened or endangered species within the project area. Any migratory species which may pass through the area should not experience any impacts from the floodwall.

3.3.10 Socioeconomic

The socioeconomic impacts of Alternative No. 3 would be limited to that segment of the project area protected by the floodwall. Short-term economic impacts would be experienced through the costs associated with the construction of the floodwall, the possible disruption of services and/or displacement of facilities. Long-term beneficial impacts would be realized through potential changes in property values, reductions in insurance premiums and protection from flooding.

3.3.11 Air Quality and Noise

During the construction phase there would be minor adverse impacts on area air quality associated with the transportation of supplies and operation of heavy duty equipment. There should be no long-term impacts on air quality from the construction of a floodwall.

The impacts of this alternative action on the level of noise would be relatively the same as those for air quality. During the short-term time period transport vehicles and heavy construction equipment would increase noise levels. The wall would be of a low to moderate height and should not have any significant effects on long-term noise levels in the area.

3.3.12 Recreation

This alternative should not affect recreation within the area. As it has been indicated the wall would be of a low to moderate height (i.e., five to eight feet) and should not block area residents' views of the Thames River as compared to

Alternative No. 2 with a dike approximately 25 feet high. The wall would be readily apparent to recreational boaters and fishermen on the river, but this should not detract from passive recreational use.

4.0 SUMMARY AND CONCLUSIONS

The potential impacts associated with the development of three flood control alternatives for Thamesville, Connecticut have been examined. Each of the alternative actions for flood damage control would provide different levels of protection to the project area and result in different types of impacts to the environment. Two of these alternatives, floodproofing (Alternative No. 1) and the construction of a floodwall (Alternative No. 3), would have essentially no measurable adverse impact on the environment. Alternative No. 2, dike and wall construction, has the potential to have significant environmental impacts.

Alternative No. 1, floodproofing, would provide the least amount of flood protection to Thamesville. Floodproofing would also have the least amount of impact upon the physical and biological environments. Only a segment of the project area would be floodproofed. The short-term costs associated with implementing this alternative would be relatively low; however, the long-term potential for damage, and the inconvenience and costs associated with moving supplies and equipment must be considered as negative aspects of this alternative.

The construction of a floodwall, Alternative No. 3, would also protect only a portion of the overall project area. It would provide flood damage control for the same area as Alternative No. 1 plus the facilities of Sawyer Displays. There would be greater short-term costs associated with constructing the floodwall and greater benefits. The floodwall would effectively protect this area with minimal long-term operating and maintenance costs. This alternative would have potential minor adverse impacts on the water quality, aquatic ecosystem, air quality and noise during the short-term construction time period. However, in the long-term the floodwall could improve these parameters by stabilizing the existing bank which is eroding into the Thames River in some areas. Other environmental impacts would be negligible.

The implementation of Alternative No. 2, earthen dike and floodwall construction, would effectively protect the entire project area. However, the costs of constructing, operating and maintaining these facilities would be significantly higher than either of the preceding alternatives. In addition, this alternative action could have potentially significant environmental impacts. Construction activities would affect the water quality and the aquatic environment of the Thames River during the short-term period, as well as air quality, noise and traffic. Once the dike is constructed there are management opportunities which could enhance the terrestrial environment. Outside the immediate project locality, there is a potential for adverse impacts on the aquatic and/or terrestrial ecosystems of the spoil disposal site and the soil, gravel and stone excavation site, dependent upon where these are.

Selection of a preferred alternative will have to be based on such criteria as:

- The level of flood protection desired in Thamesville.
- The cost effectiveness of alternative actions versus the level of flood protection which they provide.
- The impacts associated with implementing the different alternatives.
- The impacts associated with maintaining and operating the different alternatives.

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APPENDIX A

PICTORIAL OVERVIEW OF

THAMES RIVER PROJECT AREA

PHOTO 1

Project area looking north from Lehigh Gas towards Sawyer Displays

PHOTO 2

Project area looking south from dock towards Connecticut Beverage Company (CBC) and Lehigh Gas

PHOTO 3

Project area looking west from dock
toward Bushnell Place and Dahl
(between CBC and Sachem)

PHOTO 4

Project area surrounding Dahl
along access road

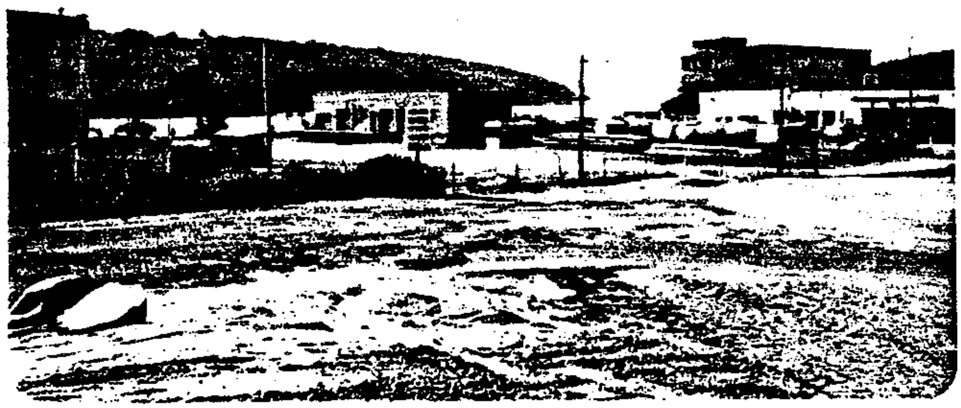

PHOTO 5

Overview of project area from
Lehigh tanks to CBC

PHOTO 6

Lehigh tanks adjacent to Sawyer Displays

PHOTO 7

Building adjacent to Sawyer Displays from railroad tracks

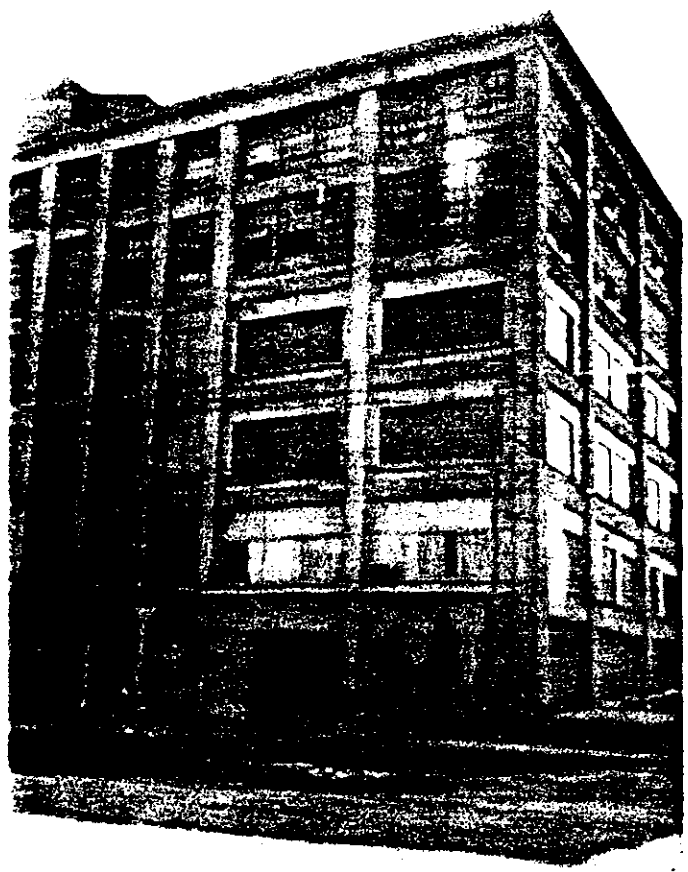

PHOTO 8

Sawyer Displays building

PHOTO 9

Edge of Sawyer Displays and
American Thermos Building
from South Street area

PHOTO 10

Vacant lot across from American
Thermos along Shipping Street
and United Metals Building

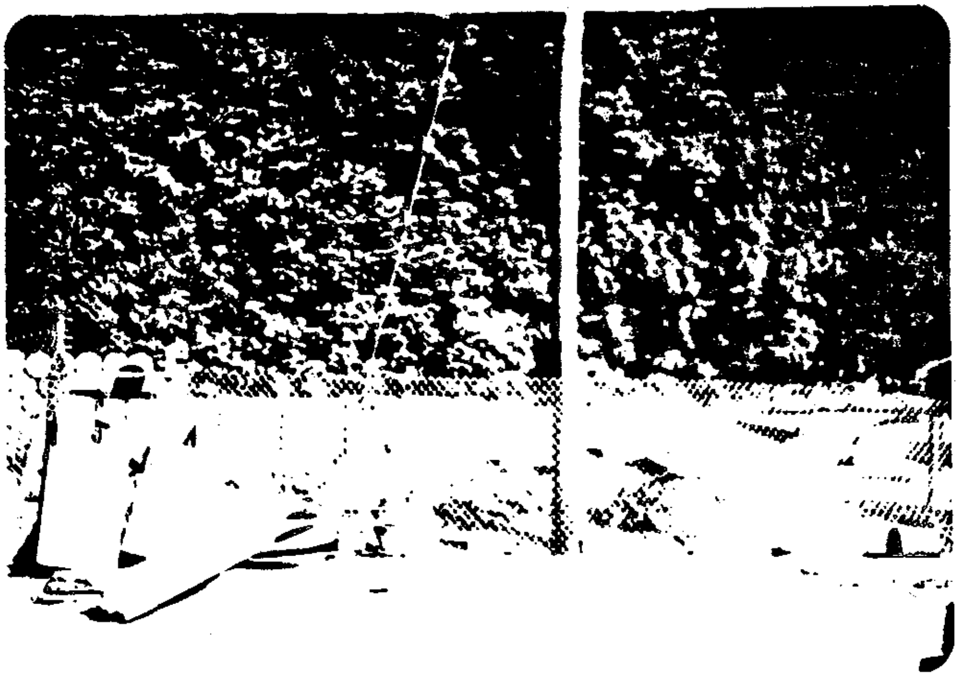

PHOTO 11

United Metals Storage Area

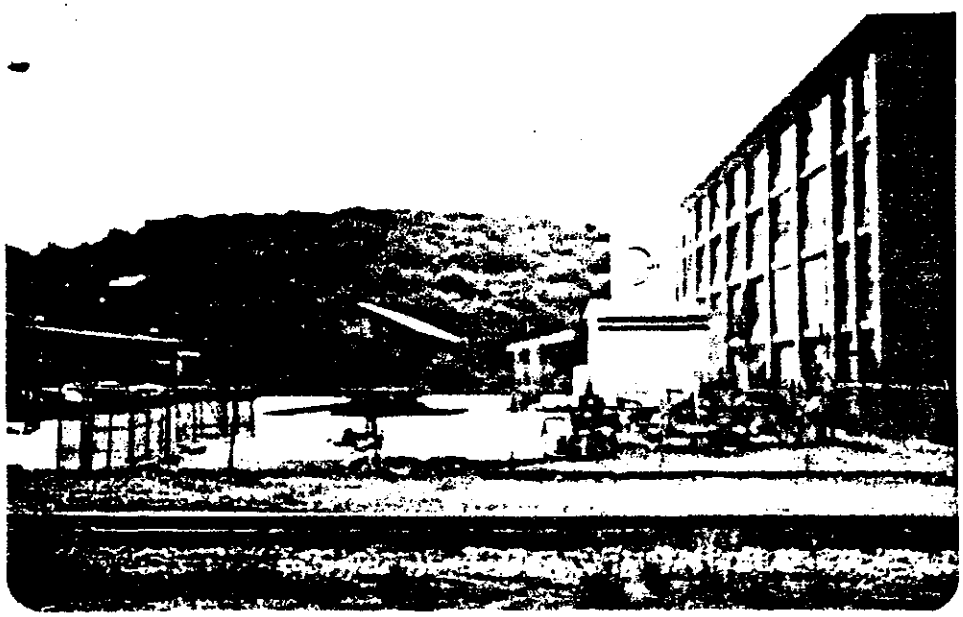

PHOTO 12

Lehigh Petroleum and American
Thermos from vacant lot

PHOTO 13

Lehigh Petroleum Complex
looking from river

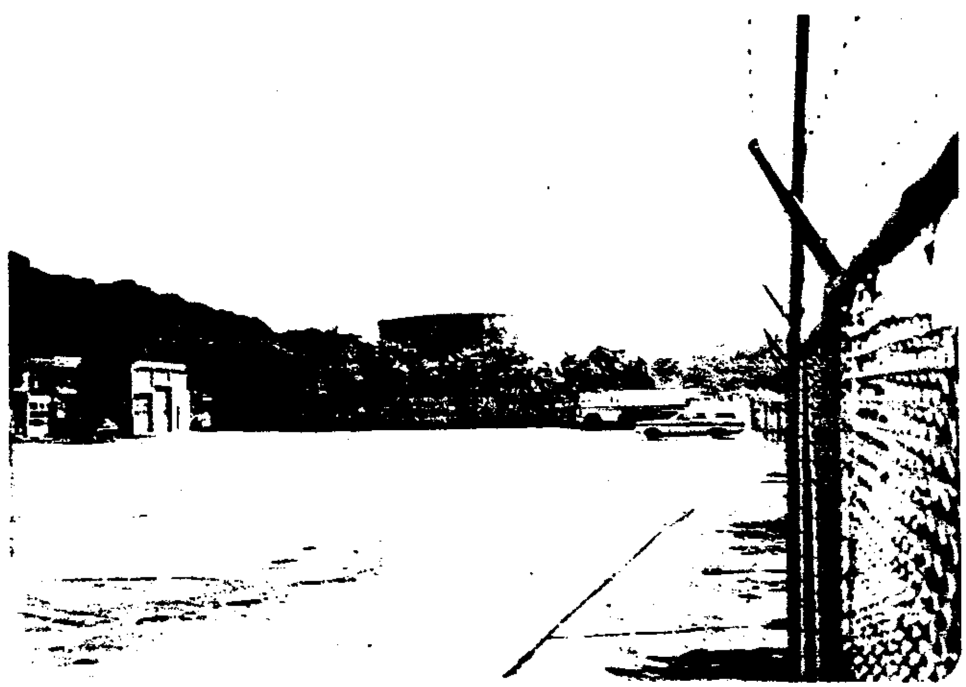

PHOTO 14

Lehigh Petroleum Complex looking along
river toward Norwich Iron

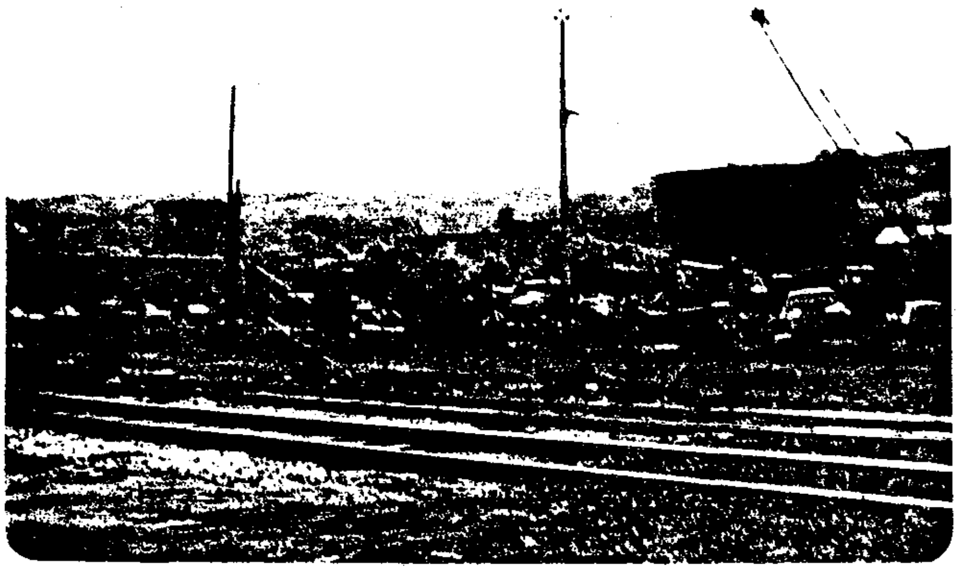

PHOTO 15

Norwich Iron from railroad track
towards river

PHOTO 16

Norwich Iron along access road

PHOTO 17

Rose Street residential area

APPENDIX B

THAMES RIVER WATER

QUALITY DATA

01127701 THAMES RIVER NEAR MOHEGAN, CT

LOCATION.--Lat 41°28'54", long 72°04'32", New London County, Hydrologic Unit 01100003, at bridge on State Highway 2A, 1.3 mi (2.1 km) east of Mohegan, 2.9 mi (4.7 km) downstream from Norwich, 0.9 mi (1.4 km) upstream from Poquetanuck Cove, and 1.2 mi (1.9 km) downstream from Trading Cove.

DRAINAGE AREA.--1,382 mi^2 (3,579 km^2).

PERIOD OF RECORD.--Water years 1963, 1974 to current year.

REMARKS.--Stream tidal and salinity affected.

WATER QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

DATE	TIME	SAM-PLING DEPTH (FEET)	SPE-CIFIC CON-DUCT-ANCE (UMHOS)	PH (UNITS)	SALIN-ITY (PPT)	TEMPER-ATURE, AIR (DEG C)	TEMPER-ATURE (DEG C)	COLOR (PLAT-INUM-COBALT UNITS)	TUR-BID-ITY (FTU)	OXYGEN, DIS-SOLVED (MG/L)	OXYGEN, DIS-SOLVED (PER-CENT SATUR-ATION)	COLI-FORM, FECAL, 0.45 UM-MF (COLS./100 ML)
OCT												
27...	1315	1.00	7680	7.2	5.0	18.0	13.0	17	2.0	9.8	97	2100
27...	1320	20.0	45500	7.9	30.0	18.0	12.0	1	4.0	1.0	11	150
NOV												
19...	1015	1.00	9700	7.5	5.0	8.0	8.0	20	2.0	10.6	92	1000
19...	1020	20.0	44000	7.9	29.0	8.0	10.0	3	2.0	.0	0	[illegible]
DEC												
21...	1055	1.00	4900	7.2	3.0	.0	.5	17	1.0	13.3	90	7[illegible]
21...	1100	20.0	47000	8.0	31.0	.0	6.0	4	4.0	7.6	74	37
JAN												
21...	1100	1.00	5900	7.1	3.0	<-5.0	.0	10	2.0	12.8	86	400
21...	1110	10.0	9800	7.3	16.0	<-5.0	1.0	10	2.0	9.8	68	400
FEB												
12...	1220	1.00	2600	6.8	2.0	1.0	.5	15	1.0	13.9	94	900
12...	1230	8.00	7840	7.2	13.0	1.0	.5	8	1.0	.2	1	520
MAR												
19...	1120	1.00	6200	7.6	4.0	10.0	5.0	15	2.0	12.4	97	120
19...	1125	22.0	47000	8.3	31.0	10.0	3.0	<1	3.0	7.4	55	K13
APR												
15...	0935	1.00	5100	7.1	3.0	13.5	7.0	--	2.0	11.6	94	42
15...	0945	23.0	47000	8.1	31.0	13.5	3.0	--	6.0	7.7	56	K11
MAY												
12...	1350	1.00	5100	7.2	3.0	26.0	17.0	15	1.0	9.4	97	80
12...	1400	10.0	46000	7.6	30.0	26.0	8.0	5	1.0	8.0	67	K3
JUN												
15...	1000	1.00	1400	6.8	1.0	25.0	14.0	35	2.0	10.3	99	880
15...	1015	20.0	19100	7.3	11.0	25.0	12.0	14	1.0	5.6	52	1100
JUL												
15...	1015	1.00	3500	7.5	2.0	28.0	25.0	18	5.0	8.8	105	560
15...	1020	20.0	41000	7.3	27.0	28.0	16.0	4	4.0	3.2	32	20
AUG												
12...	0950	1.00	5000	6.9	3.0	22.5	23.0	16	2.0	7.3	84	800
12...	1000	20.0	40000	7.1	26.0	22.5	19.0	10	1.0	.2	2	56
SEP												
01...	1245	1.00	4700	7.3	3.0	23.0	22.5	20	3.0	11.3	131	1000
01...	1250	20.0	37000	7.1	24.0	23.0	19.0	13	1.0	2.1	26	30

01127701 THAMES RIVER NEAR MOHEGAN, CT.--Continued

WATER QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

DATE	STREP-TOCOCCI FECAL, KF AGAR (COLS. PER 100 ML)	HARD-NESS (MG/L AS CACO3)	HARD-NESS NONCAR-BONATE (MG/L AS CACO3)	CALCIUM DIS-SOLVED (MG/L AS CA)	MAGNE-SIUM, DIS-SOLVED (MG/L AS MG)	ALKA-LINITY LAB (MG/L AS CACO3)	SULFATE DIS-SOLVED (MG/L AS SO4)	CHLO-RIDE, DIS-SOLVED (MG/L AS CL)	SILICA, DIS-SOLVED (MG/L AS SIO2)	SOLIDS, RESIDUE AT 180 DEG. C DIS-SOLVED (MG/L)	SOLIDS, DIS-SOLVED (TONS PER AC-FT)
OCT											
27...	1200	610	580	46	120	29	200	2300	4.9	4213	5.7
27...	35	4900	4800	310	1000	95	940	16000	1.3	29600	40.3
NOV											
19...	6000	--	--	--	--	--	410	2700	--	5170	7.0
19...	600	--	--	--	--	--	2300	18000	--	29400	40.0
DEC											
21...	800	--	--	--	--	--	150	1800	--	2880	3.9
21...	K17	--	--	--	--	--	--	--	--	27900	--
JAN											
21...	400	550	530	40	110	27	250	1800	9.8	3380	4.6
21...	260	820	790	66	160	31	440	3100	9.7	5820	7.9
FEB											
12...	760	--	--	--	--	--	11	720	--	1340	1.8
12...	800	--	--	--	--	--	420	3200	--	5410	7.4
MAR											
19...	160	--	--	--	--	--	13	1600	--	3290	4.5
19...	60	--	--	--	--	--	2300	14000	--	--	--
APR											
15...	K13	440	420	31	88	15	--	--	4.8	--	--
15...	K1	4700	4600	280	960	95	--	--	.7	--	--
MAY											
12...	K3	--	--	--	--	--	220	1300	--	3260	4.4
12...	<1	--	--	--	--	--	2200	16000	--	29900	40.7
JUN											
15...	720	--	--	--	--	--	59	370	--	790	1.1
15...	3700	--	--	--	--	--	1100	7500	--	14700	20.0
JUL											
15...	30	360	330	29	69	24	160	1100	4.0	2200	3.0
15...	130	4600	4600	310	940	92	1600	15000	1.0	28100	38.2
AUG											
12...	400	--	--	--	--	--	230	1600	--	--	--
12...	420	--	--	--	--	--	2000	14000	--	26000	35.4
SEP											
01...	240	--	--	--	--	--	190	1400	--	2780	3.8
01...	300	--	--	--	--	--	2000	18000	--	29000	39.4

DATE	SOLIDS, RESIDUE AT 105 DEG. C, TOTAL (MG/L)	NITRO-GEN, NITRATE TOTAL (MG/L AS N)	NITRO-GEN, NITRITE TOTAL (MG/L AS N)	NITRO-GEN, NO2+NO3 TOTAL (MG/L AS N)	NITRO-GEN, AMMONIA TOTAL (MG/L AS N)	NITRO-GEN, ORGANIC TOTAL (MG/L AS N)	NITRO-GEN,AM-MONIA + ORGANIC TOTAL (MG/L AS N)	NITRO-GEN, TOTAL (MG/L AS N)	PHOS-PHORUS, TOTAL (MG/L AS P)	PHOS-PHORUS, DIS-SOLVED (MG/L AS P)
OCT										
27...	4880	.47	.020	.49	.100	.85	.95	1.4	.090	.060
27...	31100	.04	.010	.05	.230	.25	.48	.53	.090	.070
NOV										
19...	5530	.59	.020	.61	.090	.50	.59	1.2	.100	.070
19...	30800	.04	.020	.06	.160	.02	.18	.24	.080	.070
DEC										
21...	3030	--	<.010	.44	.110	.62	.73	1.2	.030	.020
21...	27900	--	<.010	.05	.130	--	<.10	--	.150	.040
JAN										
21...	3480	--	<.010	.62	.130	.40	.53	1.2	.200	.030
21...	6950	--	<.010	.28	.140	.16	.30	.58	.040	.040
FEB										
12...	1350	.43	.030	.46	.100	.34	.44	.90	.030	.020
12...	5410	.63	.040	.67	.110	.34	.45	1.1	.120	.030
MAR										
19...	3660	--	<.010	.49	.110	.33	.44	.93	.040	.030
19...	30800	--	<.010	.03	.110	.20	.31	.34	.090	.040
APR										
15...	--	--	<.010	.37	.200	.07	.27	.64	.050	.040
15...	--	--	<.010	<.10	.140	.00	.10	--	.050	.040
MAY										
12...	3600	.28	.020	.30	.100	.40	.50	.80	.060	.040
12...	34000	--	.010	<.10	.160	--	<.10	--	.080	.040
JUN										
15...	--	--	<.010	.29	.080	.12	.20	.49	.060	.030
15...	13500	--	<.010	<.10	.250	.35	.60	--	.070	.040
JUL										
15...	2200	.16	.010	.17	.050	.55	.60	.77	.080	.010
15...	28200	--	.020	<.10	.310	.00	.20	--	.110	.050
AUG										
12...	--	.26	.010	.27	.120	.48	.60	.87	.090	.040
12...	25500	--	<.010	<.10	.570	.15	.72	--	.160	.090
SEP										
01...	2930	.12	.010	.13	.020	1.1	1.10	1.2	.060	.010
01...	29200	--	<.010	<.10	.300	.10	.40	<.50	.090	.070

01127701 THAMES RIVER NEAR MOHEGAN, CT.--*Continued*

WATER QUALITY DATA, WATER YEAR OCTOBER 1981 TO SEPTEMBER 1982

DATE	CADMIUM DIS- SOLVED (UG/L AS CD)	CHRO- MIUM, DIS- SOLVED (UG/L AS CR)	COPPER, DIS- SOLVED (UG/L AS CU)	IRON, DIS- SOLVED (UG/L AS FE)	LEAD, DIS- SOLVED (UG/L AS PB)	MANGA- NESE, DIS- SOLVED (UG/L AS MN)	NICKEL, DIS- SOLVED (UG/L AS NI)	ZINC, DIS- SOLVED (UG/L AS ZN)	CARBON, ORGANIC TOTAL (MG/L AS C)	METHY- LENE BLUE ACTIVE SUB- STANCE (MG/L)
OCT										
27...	<1	3	4	110	2	25	2	20	5.1	.20
27...	<1	3	2	150	1	30	3	30	3.5	.90
NOV										
19...	<1	5	10	--	<1	--	3	20	3.9	--
19...	<1	4	4	--	<1	--	1	30	2.5	--
DEC										
21...	<1	<1	2	--	<1	--	1	30	4.7	--
21...	<1	<1	2	--	<1	--	<1	40	4.0	--
JAN										
21...	<1	<1	5	70	<1	40	2	10	2.8	.20
21...	<1	<1	5	140	<1	40	2	10	3.4	.30
FEB										
12...	<1	<1	4	--	2	--	1	20	2.5	--
12...	<1	<1	10	--	1	--	3	10	3.2	--
MAR										
19...	<1	1	2	--	6	--	3	10	2.2	--
19...	<1	<1	2	--	2	--	<1	30	1.6	--
APR										
15...	1	--	2	100	2	30	<1	--	--	--
15...	1	--	1	230	2	60	<1	--	--	--
MAY										
12...	<1	<1	4	--	2	--	2	20	2.8	--
12...	2	<1	4	8	2	--	4	30	1.6	--
JUN										
15...	<1	<1	3	--	2	--	1	10	4.3	--
15...	1	<1	2	--	2	--	1	10	5.1	--
JUL										
15...	<1	2	6	50	5	<10	5	10	4.5	.12
15...	<1	4	5	160	3	80	2	30	2.3	.76
AUG										
12...	1	--	4	--	3	--	1	40	4.1	--
12...	1	--	2	--	2	--	2	20	2.7	--
SEP										
01...	<1	<1	3	--	1	--	1	<10	5.1	--
01...	<1	<1	4	--	<1	--	1	30	2.3	--

APPENDIX 6

PERTINENT CORRESPONDENCE

Office of the
STATE
HISTORIC
PRESERVATION
OFFICER
for Connecticut

59 SOUTH PROSPECT STREET - HARTFORD, CONNECTICUT 06106 - TEL: (203) 566-3005

November 21, 1985

Mr. John Wilson
Department of the Army
New England Division
Corps of Engineers
424 Trapelo Road
Waltham, MA 02254

SUBJECT: FLOOD MANAGEMENT STUDY
THAMESVILLE-NORWICH, CT

Dear Mr. Wilson:

The State Historic Preservation Office has reviewed the above-named project. This office notes that several residential and/or industrial properties located within the potential project area appear to possess local architectural or historical significance. However, we expect that the proposed flood management activities will have no effect upon these properties. This comment is conditional upon our understanding that no physical alteration is contemplated with regards to the structures located within the flood management study area. Any design change which would physically impact any property within the project area should be submitted to the State Historic Preservation Office for review and comment in accordance with the National Historic Preservation Act of 1966.

This office appreciates the opportunity to have reviewed and commented upon the project.

For further information, please contact David A. Poirier, Archaeologist.

Sincerely,

Dawn Maddox

Dawn Maddox
Deputy State Historic
Preservation Officer

DAP/PW

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

November 7, 1983

Colonel Carl B. Sciple
Division Engineer
U.S. Army Corps of Engineers
424 Trapelo Road
Waltham, MA. 02254

Dear Colonel Sciple:

Recently, Richard Quinn of your office consulted with my staff concerning new CE activities in Connecticut. As a result of that discussion, I would like to recommend two endeavors.

First, this agency very much endorses the strategy to have your agency follow-up the Long Island Sound Thamesville Tidal - Flood Management Water Resources Study by looking into non-structural techniques, especially flood warning systems for the Thamesville area. While I endorse additional efforts in the Thamesville area, it is important to note I believe implementation of a project in Thamesville must begin soon. The town of Norwich, of which Thamesville is a part, has been the subject of many flood problem studies; but to date no project has been implemented. If the CE is to initiate additional study in this area, it is imperative that it be part of detailed project planning that is directly related to project implementation. Additional flood studies in the Norwich area that are not connected directly to implementation would not be in the best interests of the state or the residents of the Norwich area.

Secondly, I am providing a list of priority areas for additional studies along our coastline. The list has been developed using a new classification of flood hazards by drainage basin. This process has resulted in the ranking of drainage basins according to their flood susceptibility. I am pleased that Grant Kelly of your staff has been involved in this project as a member of the overseeing committee. While the classification is new, and will be refined, I do believe that it represents the most objective means yet devised of ranking our flood problems. Specifically, I would like to request that the CE begin new studies to delineate flood management alternatives for coastal areas. While there are many coastal communities which have significant flood hazards, I believe that the areas most vulnerable to flood losses are, in alphabetical order:

1. East Haven and New Haven shoreline.
2. Fairfield shoreline, especially Fairfield Beach and Pine Creek.
3. Milford and West Haven shoreline, especially Bay View (Milford), the mouth of the Housatonic River (Milford), and Prospect Beach (West Haven).
4. Old Saybrook and Westbrook shoreline, especially Grove Beach (Westbrook).

Phone:
165 Capitol Avenue • Hartford, Connecticut 06106

Once again, I thank you and your staff for working so closely with this agency in seeking solutions to our flood problems. I am looking forward to initiating new projects with your agency in the near future. As with all flood related work, please contact Benjamin Warner, Director of my Water Resources Unit (203-566-7220) if you have any questions on the technical aspects of my requests.

Sincerely yours,

Stanley J. Pac

Stanley J. Pac
Commissioner

UNITED STATES
DEPARTMENT OF THE INTERIOR
FISH AND WILDLIFE SERVICE
ECOLOGICAL SERVICES
P.O. Box 1518
Concord, New Hampshire 03301

SEP 25 1979

Division Engineer
New England Division, Corps of Engineers
424 Trapelo Road
Waltham, Massachusetts 02154

Dear Sir:

This is a planning aid report prepared to assist you in your flood control study on the Thames River in Thamesville, Connecticut. The information provided is a preliminary fish and wildlife resource inventory of the study area.

The banks of the Thames River in the study area have been heavily urbanized. Industrial and residential developments run right to the shoreline. The vegetation remaining is that which is consistent with a developed locale. The area still provides habitat for urban wildlife including songbirds and small mammals such as rabbits and squirrels.

The river is a broad tidal estuary extending 12 miles northward from New London Harbor to Norwich. In past decades, the Thames has been degraded by industrial and municipal pollution. Inadequately treated waste waters and direct industrial discharges contributed high levels of organics and heavy metals to the system. However, with the passage of the Federal Water Pollution Control Act combined with State and Federal enforcement, the water quality is improving. A saltwater wedge is experienced all the way to Norwich, producing a buffering effect on river temperature.

The river supports a very significant fishery population. Its waters are used for feeding and as spawning and nursery grounds for a variety of species. There remain small commercial fisheries for bluefish, Atlantic tomcod, striped bass, winter flounder, American eel and alewife. The Thames supports a heavily utilized sport fishery for winter flounder, striped bass, white perch, American smelt, bluefish and Atlantic tomcod. Mummichog and Atlantic menhaden are the most common forage species.

The Connecticut Department of Environmental Protection has placed a high priority on the restoration of anadromous fish in the two principal tributaries to the Thames River, the Shetucket and Quinebaug Rivers. Historical records show that the drainage formerly supported sizable runs of American shad, Atlantic salmon and alewives. Studies partly funded under the Anadromous Fish Act (PL 89-304) are being conducted to determine the potential for establishing runs of Atlantic salmon, coho salmon, sea-run brown trout, American shad, alewife and blueback herring. Restoration plans will include the construction of fishways on the dams to provide upstream access. The preliminary results of this study have been reported in:

Hames, Richard L. (Ed.). 1975. An Evaluation of the Fishery Resources of the Thames River Watershed, Connecticut. Storrs Agricultural Experiment Station. Bulletin 435.

The final report is being drafted and should be available for review by the end of November 1979.

Although their populations were once depleted, blue crab is making a comeback in the estuary and does provide a small recreational fishery. The river produces oysters and hard-shell and soft-shell clams but they are not taken for direct consumption due to high coliform counts.

The river provides very limited habitat for dabbling ducks but is very important to diving ducks which are distributed along the estuarine reach. Waterfowl usage is primarily for wintering and during migration periods. During the fall, many sportsmen hunt the river shoreline, primarily for black duck, goldeneye and mallard.

We understand that flood control alternatives are in the initial stage of review. We recommend that nonstructural alternatives be pursued such as flood proofing, which would have minimal adverse impacts on this natural resource. We appreciate the opportunity to comment on this local protection study. We request the opportunity to provide additional comments as plans are developed.

Sincerely yours,

Gordon E. Beckett

Gordon E. Beckett
Supervisor

Enclosures

Enclosure (1)

Seasonal means of temperature, dissolved oxygen, and salinity near project site.

Season	Depth	Temperature	D.O.	Salinity
Winter	1 m	1.3	13.5	1
	5 m	2.3	10.9	25
Spring	1 m	8.5	12.3	3
	5 m	6.3	10.0	24
Summer	1 m	23.8	4.9	8
	5 m	18.1	0.3	23
Autumn	1 m	17.5	6.5	5
	5 m	18.8	0.7	31

Temperature = (C)
D.O. = (mg/1)
Salinity = (ppt)

Enclosure (2)

Common fish species found in the Thames River estuary.

Blueback herring (Alosa aestivalis)
Hickory shad (Alosa mediocris)
Alewife (Alosa pseudoharengus)
American shad (Alosa sapidissima)
American eel (Anguilla rostrata)
Fourspine stickleback (Apeltes quadracus)
Atlantic menhaden (Brevoortia tyrannus)
White sucker (Catostomus commersoni)
Atlantic herring (Clupea harengus)
Weakfish (Cynoscion regalis)
Carp (Cyprinus carpio)
Chain pickerel (Esox niger)
Tessellated darter (Etheostoma omstedi)
Banded killifish (Fundulus diaphanus)
Mummichog (Fundulus heteroclitus)
White catfish (Ictalurus catus)
Tidewater silverside (Menidia beryllina)
Atlantic tomcod (Microgadus tomcod)
Largemouth bass (Micropterus salmoides)
White perch (Morone americana)
Striped bass (Morone saxatilis)
Spottail shiner (Notropis hudsonius)
Atlantic mackerel (Scomber scombrus)
Smelt (Osmerus mordax)
Yellow perch (Perca flavescens)
Bluefish (Pomatomus saltatrix)
Winter flounder (Pseudopleuronectes americanus)
Brown trout (Salmo trutta)